

# OPTICAL ELEMENT RETRACTING MECHANISM

## FOR A PHOTOGRAPHING LENS

### BACKGROUND OF THE INVENTION

#### 5 1. Field of the Invention

The present invention relates to a mechanism, incorporated in a retractable photographing (imaging) lens (retractable lens barrel), for retracting a part of a plurality of optical elements, constituting a 10 photographing optical system, to a position deviating from the photographing optical axis of the photographing optical system when the photographing lens is fully retracted. The present invention also relates to a mechanism, which can be incorporated in a photographing 15 lens, for positioning a supported element such as an internal element of the photographing lens.

#### 2. Description of the Related Art

Miniaturization of lens barrels incorporated in optical devices such as cameras has been in increasing 20 demand. Above all, further miniaturization of retractable photographing lenses, specifically the length thereof in a non-operating state, has been in strong demand. To meet such demands, the inventor of the present invention has proposed a retractable 25 photographing lens disclosed in United States Patent

Application No.10/368342 in which an optical element of a photographing optical system is retracted to a position deviating from the photographing optical axis of the photographing optical system, and at the same time, the  
5 optical element (together with other optical elements of the photographing optical system) is retracted toward the picture plane when the photographing lens is fully retracted. The mechanism achieving such complicated operations of the optical elements is required to operate  
10 with a high degree of accuracy. Moreover, it is required that the position of the retractable optical element can be easily adjusted with a high degree of positioning accuracy with a simple structure. Furthermore, it is required to provide the photographing lens with a simple  
15 two-dimensional positioning device with which the position of a supported element (e.g., a movable lens frame or holder) can be adjusted two-dimensionally in directions lying a flat plane.

20           SUMMARY OF THE INVENTION

The present invention provides a mechanism, incorporated in a retractable photographing lens (retractable lens barrel), which is capable of retracting an optical element of a photographing optical system to  
25 a position deviating from the photographing optical axis

of the photographing optical system, and at the same time,  
retracting the optical element toward the picture plane  
with a high degree of accuracy, wherein the mechanism is  
provided with a positioning structure with which the  
5 position of the optical element can be adjusted. The  
present invention provides a simple mechanism, which can  
be incorporated in a photographing lens, for positioning  
a supported element such as an internal element of the  
photographing lens, wherein the position of the supported  
10 element can be easily adjusted with the positioning  
mechanism.

According to an aspect of the present invention, an  
optical element retracting mechanism for a retractable  
lens including an optical system having a plurality of  
15 optical elements is provided, the optical element  
retracting mechanism including a linearly movable ring  
configured to be guided along an optical axis of the  
optical system without rotating, the linearly movable  
ring retracting toward a plane along the optical axis when  
20 the retractable lens moves from an operational state to  
a fully-retracted state; a swingable holder mounted on  
a pivot and pivotable about the pivot, and further  
positioned inside and supported by the linearly movable  
ring, the swingable holder supporting a retractable  
25 optical element as one of the plurality of optical

elements; a position-controller configured to hold the swingable holder such that the retractable optical element remains on the optical axis when the retractable lens is in the operational state, the position-controller  
5 further configured to rotate the swingable holder about the pivot such that the retractable optical element retracts to a position which deviates from the optical axis when the linearly movable ring, together with the swingable holder, retracts toward the plane; at least one  
10 support plate supporting the pivot, and including a first elongated hole and a second elongated hole, a direction of elongation of the first elongated hole and a direction of elongation of the second elongated hole being generally orthogonal to each other; a support plate fixing device  
15 fixing the at least one support plate to the linearly movable ring, wherein the support plate fixing device is configured to allow the at least one support plate to move relative to the linearly movable ring in directions lying in a plane generally orthogonal to the optical axis when  
20 the support plate fixing device is in a released state; a first rotatable shaft having a first axis substantially parallel to the optical axis, supported by the linearly movable ring to be rotatable about the first axis, and having at least one first eccentric pin which is engaged  
25 in the first elongated hole to be movable therein in the

direction of elongation of the first elongated hole, the  
at least one first eccentric pin having an axis eccentric  
to the first axis, wherein when the first rotatable shaft  
is rotated, a first movement force is applied on the at  
5 least one support plate in a direction generally  
orthogonal to the direction of elongation of the first  
elongated hole; a second rotatable shaft having a second  
axis substantially parallel to the optical axis,  
supported by the linearly movable ring to be rotatable  
10 about the second axis, and having at least one second  
eccentric pin which is engaged in the second elongated  
hole to be movable therein in the direction of elongation  
of the second elongated hole, the at least one second  
eccentric pin having an axis eccentric to the second axis,  
15 wherein when the second rotatable shaft is rotated, a  
second movement force is applied on the at least one  
support plate in a direction generally orthogonal to the  
direction of elongation of the second elongated hole; and  
a movement direction setting device, provided on the  
20 support plate and the linearly movable ring, and setting  
the direction of movement of the at least one support plate  
in a plane substantially orthogonal to the optical axis  
when the at least one of the first and second movement  
force is applied on the at least one support plate by at  
25 least one of the rotation of the first rotatable shaft

and the rotation of the second rotatable shaft when the support plate fixing device is in the released state.

The movement direction setting device can include a third elongated hole formed on the at least one support plate so that a direction of elongation of the third elongated hole is substantially parallel to one of the direction of elongation of the first elongated hole and the direction of elongation of the second elongated hole, and a projection projecting from the linearly movable ring and engaged in the third elongated hole to be movable therein. A rotation of one of the first rotatable shaft and the second rotatable shaft causes the at least one support plate to move linearly along a direction of elongation of one of the first elongated hole and the second elongated hole with which the other of the first rotatable shaft and the second rotatable shaft is engaged. A rotation of the other of the first rotatable shaft and the second rotatable shaft causes the at least one support plate to move non-linearly along a direction substantially orthogonal to the direction of elongation of the one of the first elongated hole and the second elongated hole.

It is desirable for two of the first, second and third elongated holes, the directions of elongation thereof being substantially parallel to each other, to

be formed at different positions in both a lengthwise direction of each of the two elongated holes and a widthwise direction of each of the two elongated holes, and wherein a space between the two elongated holes in 5 the lengthwise direction is greater than a space between the two elongated holes in the widthwise direction.

It is desirable for a remaining one of the first elongated hole, the second elongated hole and the third elongated hole to be positioned between the two elongated 10 holes in the lengthwise direction, and is proximately positioned to one of the two elongated holes.

The pivot shaft can be positioned between two of the first, second and third elongated holes the directions of elongation of which are substantially parallel to each 15 other in a lengthwise direction of each of the two elongated holes.

The movement direction setting device can include a third elongated hole formed on the at least one support plate so that a direction of elongation of the third elongated hole is inclined to both the direction of elongation of the first elongated hole and the direction of elongation of the second elongated hole; and a projection projecting from the linearly movable ring to be engaged in the third elongated hole to be movable 20 therein. A rotation of one of the first rotatable shaft 25

and the second rotatable shaft causes the support plate to move non-linearly along a direction including a component of the direction of elongation of the second elongated hole, in which the second eccentric pin of the 5 second rotatable shaft is engaged. A rotation of the other of the first rotatable shaft and the second rotatable shaft causes the support plate to move non-linearly along a direction including a component of the direction of elongation of the first elongated hole, in 10 which the first eccentric pin of the first rotatable shaft is engaged.

It is desirable for the support plate to include a pair of support plates fixed to front and rear surfaces of the linearly movable ring in the optical axis direction 15 and supports opposite ends of the pivot, respectively. A pair of the first elongated holes and a pair of the second elongated holes are formed on the pair of support plates, respectively, such that the pair of first elongated holes face each other in the optical axis direction and extend 20 generally parallel to each other, and such that the pair of second elongated holes face each other in the optical axis direction and extend parallel to each other, a direction of elongation of the pair of first elongated holes being generally orthogonal to a direction of 25 elongation of the pair of second elongated holes. The

first rotatable shaft includes a pair of the first eccentric pins at opposite ends thereof, each of the pair of first eccentric pins having an axis eccentric to the first axis, the pair of first eccentric pins respectively engaged in the pair of first elongated holes. The second rotatable shaft includes a pair of the second eccentric pins at opposite ends thereof, each of the pair of second eccentric pins having an axis eccentric to the second axis, the pair of second eccentric pins respectively engaged in the pair of second elongated holes.

It is desirable for the pair of first eccentric pins to have a common axis eccentric to the first axis of the first rotatable shaft, and the pair of second eccentric pins have a common axis eccentric to the second axis of the second rotatable shaft. The pair of support plates are movable relative to the linearly movable ring without changing a relative position between the pair of support plates, by rotating at least one of the first rotatable shaft and second rotatable shaft, when the support plate fixing device is in the released state.

The movement direction setting device can include a pair of third elongated holes formed on the pair of support plates, respectively; and a pair of front and rear projections projecting from front and rear of the linearly movable ring to be engaged in the pair of third elongated

holes to be movable therein, respectively.

The linearly movable ring can include a pair of generally parallel flat surfaces which are separate from each other in the optical axis direction, and which extend 5 in a direction generally orthogonal to the optical axis, the pair of support plates being pressed against the pair of parallel flat surfaces and are fixed thereto by the support plate fixing device, respectively.

The optical element retracting mechanism can 10 further include an internal optical element positioned inside the linearly movable ring on one of opposite sides of the retractable optical element in the optical axis direction, wherein the pair of support plates are attached to the opposite ends of the linearly movable ring and 15 positioned on opposite sides of the internal optical element in the optical axis direction, respectively.

The internal optical element can include at least one of a shutter and a diaphragm.

The support plate fixing device can include a screw 20 hole on one of the pair of support plates and penetrating therethrough in the optical axis direction; a screw insertion hole on the other of the pair of support plates and penetrating therethrough in the optical axis direction; and a set screw in the screw insertion hole 25 and screwed through the screw hole.

The swingable holder can further include a cylindrical lens holder portion which holds the retractable optical element, a pivoted cylindrical portion fitted on a pivot and rotatable on the pivot, and  
5 a swing arm portion extending between the cylindrical lens holder and the pivoted cylindrical portion to connect the cylindrical lens holder to the pivoted cylindrical portion.

The position-control device can include a spring  
10 configured to bias the swingable holder to rotate in a direction to position the retractable optical element on the optical axis; and a cam mechanism which rotates the swingable holder to the deviated position from the optical axis, against the biasing force of the spring, when the  
15 linearly movable ring, together with the swingable holder, retracts toward the plane.

The plurality of optical elements can include at least one rear optical element positioned behind the retractable optical element when the retractable lens is  
20 in the operational state. The retractable optical element is positioned in an off-axis space radially outside an on-axis space in which the rear optical element is positioned, so that the retractable optical element and the rear optical element are in a same positional range  
25 in the optical axis direction, when the retractable lens

is in the fully-retracted state.

It is desirable for the pivot to extend generally parallel to the optical axis.

The retractable optical element can be a lens group.

5       The optical system can be a zoom photographing optical system, and the retractable optical element can be a lens group as a part of the zoom photographing optical system.

10      The optical element retracting mechanism can be incorporated in a digital camera.

It is desirable for each of the first elongated hole and the second elongated hole to be formed as a through hole which penetrates through the at least one support plate; wherein an end of the first eccentric pin includes 15 a first operating portion via which the first eccentric pin can be rotated. An end of the second eccentric pin includes a second operating portion via which the second eccentric pin can be rotated.

It is desirable for at least one of the pair of first 20 elongated holes and at least one of the pair of second elongated holes to be formed as through holes which penetrate the pair of support plates, respectively. An end of one of the pair of first eccentric pins engaged in the through hole can include a first operating portion 25 via which the one of the pair of first eccentric pins can

be rotated. An end of one of the pair of second eccentric pins which is engaged in the through hole can include a second operating portion via which the one of the pair of second eccentric pins can be rotated.

5 It is desirable for the first operating portion and second operating portion to face a frontward direction in the optical axis direction, respectively. The optical element retracting mechanism further includes an outer barrel which surrounds the linearly movable ring, and is  
10 provided with a radially inward flange in front of the linearly movable ring. The radially inward flange includes a first through hole which penetrates through the radially inward flange in the optical axis direction so that the first operating portion is accessible from  
15 front of the linearly movable ring through the first through hole. The radially inward flange includes a second through hole which penetrates through the radially inward flange in the optical axis direction so that the second operating portion is accessible from the front of  
20 the linearly movable ring through the second through hole.

The retractable lens can include a lens barrier mechanism detachably attached to a front part of the radially inward flange to cover the first through hole and the second through hole.

25 It is desirable for the outer barrel to support one

of the plurality of optical elements positioned in front of the retractable optical element, the outer barrel retracting toward the plane together with the linearly movable ring along the optical axis, when the retractable 5 lens moves from the operational state to the fully-retracted state.

The support plate fixing device can include a screw hole formed on one of the pair of support plates to penetrate therethrough in the optical axis direction; a 10 screw insertion hole on the other of the pair of support plates and penetrating therethrough in the optical axis direction; and a set screw in the screw insertion hole and screwed through at least one screw hole. One of opposite ends of the set screw which faces a side toward 15 which the first operating portion and the second operation portion are directed includes a third operating portion via which the set screw can be rotated.

It is desirable for the third operating portion of the set screw to face toward a forward direction in the 20 optical axis direction, wherein the optical element retracting mechanism further includes an outer barrel which surrounds the linearly movable ring, and is provided with a radially inward flange positioned in front of the linearly movable ring, wherein the radially inward flange 25 includes at least one through hole which penetrates

through the radially inward flange in the optical axis direction, the third operating portion of the set screw accessible from front of the linearly movable ring through the through hole.

5       The retractable lens can include a lens barrier mechanism detachably attached to a front part of the radially inward flange to cover the through hole.

It is desirable for the outer barrel to support one of the plurality of optical elements positioned in front  
10 of the retractable optical element, the outer barrel retracting toward the plane together with the linearly movable ring along the optical axis when the retractable lens moves from the operational state to the fully-retracted state.

15       Each of the first operating portion and the second operating portion can include a slot in which an adjusting tool can be engaged.

Each of the first operating portion and the second operating portion can include a slot in which an adjusting  
20 tool can be engaged.

In another embodiment, an optical element retracting mechanism for a retractable lens including an optical system having a plurality of optical elements is provided, the optical element retracting mechanism including a linearly movable ring configured to be guided

along an optical axis of the optical system without rotating, and which retracts toward a plane along the optical axis when the retractable lens moves from an operational state to a fully-retracted state; a swingable 5 holder on a pivot and swingable about the pivot, and further positioned inside the linearly movable ring to be supported thereby, the swingable holder supporting a retractable optical element as one of the plurality of optical elements; a position-controller holding the 10 swingable holder such that the retractable optical element remains on the optical axis when the retractable lens is in the operational state, and further rotating the swingable holder about the pivot such that the retractable optical element retracts to a position which 15 deviates from the optical axis when the linearly movable ring, together with the swingable holder, retracts toward the plane; a pair of support plates which are fixed to front and rear surfaces of the linearly movable ring in the optical axis direction to support opposite ends of 20 the pivot, respectively, wherein a pair of first elongated holes and a pair of second elongated holes are located on the pair of support plates, respectively, such that the pair of first elongated holes face each other in the optical axis direction and extend generally parallel to 25 each other, and such that the pair of second elongated

holes face each other in the optical axis direction and extend generally parallel to each other, a direction of elongation of the pair of first elongated holes and a direction of elongation of the pair of second elongated 5 holes being generally orthogonal to each other; a support plate fixing device fixing the pair of support plates to the linearly movable ring, wherein the support plate fixing device allows the pair of support plates to move relative to the linearly movable ring in directions lying 10 in a plane generally orthogonal to the optical axis when the support plate fixing device is in a released state; a first rotatable shaft having a first axis generally parallel to the optical axis, supported by the linearly movable ring to be rotatable about the first axis, and 15 having a pair of first eccentric pins at opposite ends of the first rotatable shaft, each of the pair of first eccentric pins having an axis eccentric to the first axis, the pair of first eccentric pins being respectively engaged in the pair of first elongated holes to be movable 20 therein in the direction of elongation of the pair of first elongated holes, wherein when the first rotatable shaft is rotated, a first movement force is applied on the pair of support plates in a direction generally orthogonal to the direction of elongation of the first elongated hole; 25 a second rotatable shaft having a second axis generally

parallel to the optical axis, supported by the linearly movable ring to be rotatable about the second axis, and having a pair of second eccentric pins at opposite ends of the second rotatable shaft, each of the pair of second eccentric pins having an axis eccentric to the second axis, the pair of second eccentric pins being respectively engaged in the pair of second elongated holes of the pair of support plates to be movable therein in the direction of elongation of the pair of second elongated holes, wherein when the second rotatable shaft is rotated, a second movement force is applied on the pair of support plates in a direction generally orthogonal to the direction of elongation of the second elongated hole; and a movement direction setting device, provided on the pair of support plates and the linearly movable ring and setting the direction of movement of the pair of support plates in a plane generally orthogonal to the optical axis when at least one of the first and second movement force is applied on the pair of support plates by a respective at least one of the rotation of the first rotatable shaft and the rotation of the second rotatable shaft when the support plate fixing device is in the released state.

The present disclosure relates to subject matter contained in Japanese Patent Application Nos. 2002-247338 (filed on August 27, 2002), 2003-25414 (filed on February

3, 2003) and 2003-25416 (filed on February 3, 2003) which are expressly incorporated herein by reference in their entireties.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described below in detail with reference to the accompanying drawings in which:

Figure 1 is an exploded perspective view of an 10 embodiment of a zoom lens according to the present invention;

Figure 2 is an exploded perspective view of a structure supporting a first lens group of the zoom lens;

Figure 3 is an exploded perspective view of a 15 structure supporting a second lens group of the zoom lens;

Figure 4 is an exploded perspective view of a lens barrel advancing-retracting structure of the zoom lens for advancing and retracting a third external barrel from a stationary barrel;

20 Figure 5 is a perspective view, partly exploded, of the zoom lens, showing a fixing procedure of a viewfinder unit to the zoom lens and a fixing procedure of a gear train to the zoom lens;

Figure 6 is a perspective view of a zoom lens 25 assembly made from the elements shown in Figure 5;

Figure 7 is a side elevational view of the zoom lens assembly shown in Figure 6;

Figure 8 is a perspective view of the zoom lens assembly shown in Figure 6, viewed obliquely from behind;

5       Figure 9 is an axial cross sectional view of an embodiment of a digital camera incorporating the zoom lens assembly shown in Figures 6 through 8, wherein an upper half above a photographing optical axis and a lower half below the photographing optical axis show a state of the  
10      zoom lens at telephoto extremity and a state of the zoom lens at wide-angle extremity, respectively;

Figure 10 is an axial cross sectional view of the digital camera shown in Figure 9 in the retracted state of the zoom lens;

15       Figure 11 is a developed view of the stationary barrel shown in Figure 1;

Figure 12 is a developed view of a helicoid ring shown in Figure 4;

20       Figure 13 is a developed view of the helicoid ring shown in Figure 1, showing a structure of the inner peripheral surface thereof by broken lines;

Figure 14 is a developed view of the third external barrel shown in Figure 1;

25       Figure 15 is a developed view of a first linear guide ring shown in Figure 1;

Figure 16 is a developed view of a cam ring shown  
in Figure 1;

Figure 17 is a developed view of the cam ring shown  
in Figure 1, showing a structure of the inner peripheral  
5 surface thereof by broken lines;

Figure 18 is a developed view of a second linear  
guide ring shown in Figure 1;

Figure 19 is a developed view of a second lens group  
moving frame shown in Figure 1;

10 Figure 20 is a developed view of a second external  
barrel shown in Figure 1;

Figure 21 is a developed view of a first external  
barrel shown in Figure 1;

15 Figure 22 is a conceptual diagram of elements of the  
zoom lens, showing the relationship among these elements  
in relation to the operations thereof;

20 Figure 23 is a developed view of the helicoid ring,  
the third external barrel and the stationary barrel,  
showing the positional relationship thereamong in the  
retracted state of the zoom lens;

Figure 24 is a developed view of the helicoid ring,  
the third external barrel and the stationary barrel,  
showing the positional relationship thereamong at the  
wide-angle extremity the zoom lens;

25 Figure 25 is a developed view of the helicoid ring,

the third external barrel and the stationary barrel, showing the positional relationship among thereamong at the telephoto extremity the zoom lens;

Figure 26 is a developed view of the helicoid ring,  
5 the third external barrel and the stationary barrel, showing a positional relationship thereof;

Figure 27 is a developed view of the stationary barrel, showing the positions of a set of rotational sliding projections of the helicoid ring with respect to  
10 the stationary barrel in the retracted state of the zoom lens;

Figure 28 is a view similar to that of Figure 27, showing the positions of the set of rotational sliding projections of the helicoid ring with respect to the  
15 stationary barrel at the wide-angle extremity of the zoom lens;

Figure 29 is a view similar to that of Figure 27, showing the positions of the set of rotational sliding projections of the helicoid ring with respect to the  
20 stationary barrel at the telephoto extremity of the zoom lens;

Figure 30 is a view similar to that of Figure 27, showing the positions of the set of rotational sliding projections of the helicoid ring with respect to the  
25 stationary barrel;

Figure 31 is a cross sectional view taken along M2-M2 line shown in Figure 27;

Figure 32 is a cross sectional view taken along M1-M1 line shown in Figure 23;

5       Figure 33 is an enlarged cross sectional view of a portion of the upper half of the zoom lens shown in Figure 9;

Figure 34 is an enlarged cross sectional view of a portion of the lower half of the zoom lens shown in Figure 10 9;

Figure 35 is an enlarged cross sectional view of a portion of the upper half of the zoom lens shown in Figure 10;

15     Figure 36 is an enlarged cross sectional view of a portion of the lower half of the zoom lens shown in Figure 10;

Figure 37 is an enlarged perspective view of a portion of the connecting portion between the third external barrel and the helicoid ring;

20     Figure 38 is a view similar to that of Figure 37, showing a state where a stop member has been removed;

Figure 39 is a view similar to that of Figure 38, showing a state where the third external barrel and the helicoid ring have been disengaged from each other in the 25 optical axis direction from the state shown in Figure 38;

Figure 40 is a perspective view of a portion of the stationary barrel, the stop member and a set screw therefor, showing a state where the stop member and the set screw have been removed from the stationary barrel;

5       Figure 41 is a perspective view similar to that shown in Figure 40, showing a state where the stop member is properly fixed the stationary barrel via the set screw;

10      Figure 42 is an enlarged developed view of a portion of helicoid ring in relation to a corresponding portion of the stationary barrel;

15      Figure 43 is a view similar to that of Figure 42, showing the positional relationship between the specific rotational sliding projection of the helicoid ring and the circumferential groove of the stationary barrel;

20      Figure 44 is a developed view of the third external barrel and the first linear guide ring in relation to a set of roller followers fixed to the cam ring, showing the positional relationship between the helicoid ring and the stationary barrel in the retracted state of the zoom lens;

25      Figure 45 is a view similar to that of Figure 44, showing the positional relationship between the helicoid ring and the stationary barrel at the wide-angle extremity of the zoom lens;

Figure 46 is a view similar to that of Figure 44,

showing the positional relationship between the helicoid ring and the stationary barrel at the telephoto extremity of the zoom lens;

Figure 47 is a view similar to that of Figure 44,  
5 showing the positional relationship between the helicoid ring and the stationary barrel;

Figure 48 is a developed view of the helicoid ring and the first linear guide ring, showing the positional relationship therebetween in the retracted state of the  
10 zoom lens;

Figure 49 is a view similar to that of Figure 48, showing the positional relationship between the helicoid ring and the first linear guide ring at the wide-angle extremity of the zoom lens;

15 Figure 50 is a view similar to that of Figure 48, showing the positional relationship between the helicoid ring and the first linear guide ring at the telephoto extremity of the zoom lens;

Figure 51 is a view similar to that of Figure 48,  
20 showing the positional relationship between the helicoid ring and the first linear guide ring;

Figure 52 is a developed view of the cam ring, the first external barrel, the second external barrel and the second linear guide ring, showing the positional  
25 relationship thereamong in the retracted state of the zoom

lens;

Figure 53 is a view similar to that of Figure 52, showing the positional relationship among the cam ring, the first external barrel, the second external barrel and 5 the second linear guide ring at the wide-angle extremity of the zoom lens;

Figure 54 is a view similar to that of Figure 52, showing the positional relationship among the cam ring, the first external barrel, the second external barrel and 10 the second linear guide ring at the telephoto extremity of the zoom lens;

Figure 55 is a view similar to that of Figure 52, showing the positional relationship among the cam ring, the first external barrel, the second external barrel and 15 the second linear guide ring;

Figure 56 is an exploded perspective view of elements of the zoom lens, showing a state where the third external barrel has been removed from the first linear guide ring;

20 Figure 57 is an exploded perspective view of elements of the zoom lens, showing a state where the second external barrel and a follower-biasing ring spring have been removed from the block of the zoom lens shown in Figure 56;

25 Figure 58 is an exploded perspective view of

elements of the zoom lens, showing a state where the first external barrel has been removed from the block of the zoom lens shown in Figure 57;

Figure 59 is an exploded perspective view of 5 elements of the zoom lens, showing a state where the second linear guide ring has been removed from the block of the zoom lens shown in Figure 58 while the set of roller followers have been removed from the cam ring included in the block;

10       Figure 60 is a developed view of the helicoid ring, the third external barrel, the first linear guide ring and the follower-biasing ring spring in relation to the set of roller followers fixed to the cam ring, showing the positional relationship thereamong in the retracted 15 state of the zoom lens;

Figure 61 is a view similar to that of Figure 60, showing the positional relationship among the helicoid ring, the third external barrel and the first linear guide ring at the wide-angle extremity of the zoom lens;

20       Figure 62 is a view similar to that of Figure 60, showing the positional relationship among the helicoid ring, the third external barrel and the first linear guide ring at the telephoto extremity of the zoom lens;

25       Figure 63 is a view similar to that of Figure 60, showing the positional relationship among the helicoid

ring, the third external barrel and the first linear guide ring;

Figure 64 is an enlarged developed view of portions of the third external barrel and the helicoid ring in relation to the set of roller followers fixed to the cam ring, viewed from radially inside the third external barrel and the helicoid ring;

Figure 65 is a view similar to that of Figure 64, showing a state where the helicoid ring is rotated in a lens barrel advancing direction thereof;

Figure 66 is an enlarged developed view of portions of the third external barrel and the helicoid ring shown in Figure 64;

Figure 67 is an enlarged developed view of portions of a front rind and a rear ring of a comparative example which are to be compared with the third external barrel and the helicoid ring shown in Figures 64 through 66;

Figure 68 is a view similar to that of Figure 67, showing a state where the rear ring has slightly rotated with respect to the front ring from the state shown in Figure 67;

Figure 69 is a magnified view of a part of the drawing shown in Figure 60 (Figure 44);

Figure 70 is a magnified view of a part of the drawing shown in Figure 61 (Figure 45);

Figure 71 is a magnified view of a part of the drawing shown in Figure 62 (Figure 46);

Figure 72 is a magnified view of a part of the drawing shown in Figure 63 (Figure 47);

5       Figure 73 is an axial cross sectional view of an upper half of elements of a linear guide structure of the zoom lens shown in Figures 5 and 10, showing the linear guide structure at the wide-angle extremity of the zoom lens;

10       Figure 74 is a view similar to that of Figure 73, showing the linear guide structure at the wide-angle extremity of the zoom lens;

15       Figure 75 is a view similar to that of Figure 74, showing the linear guide structure in the retracted state of the zoom lens;

20       Figure 76 is a perspective view of a subassembly of the zoom lens shown in Figures 5 through 10 which includes the first external barrel, the external barrel, the second linear guide ring, the cam ring and other elements, showing the positional relationship between the first external barrel and the second linear guide ring that are positioned radially inside and outside the cam ring, respectively;

25       Figure 77 is a perspective view of a subassembly of the zoom lens shown in Figures 5 through 10 which includes

all the elements shown in Figure 77 and the first linear guide ring, showing a state where the first external barrel has been extended forward to its assembling/disassembling position;

5       Figure 78 is a perspective view of the subassembly shown in Figure 77, viewed obliquely from behind the subassembly;

10      Figure 79 is a developed view of the cam ring, the second lens group moving frame and the second linear guide ring, showing the positional relationship thereamong in the retracted state of the zoom lens;

15      Figure 80 is a view similar to that of Figure 79, showing the positional relationship among the cam ring, the second lens group moving frame and the second linear guide ring at the wide-angle extremity of the zoom lens;

      Figure 81 is a view similar to that of Figure 79, showing the positional relationship among the cam ring, the second lens group moving frame and the second linear guide ring at the telephoto extremity of the zoom lens;

20      Figure 82 is a view similar to that of Figure 79, showing a positional relationship among the cam ring, the second lens group moving frame and the second linear guide ring;

25      Figure 83 is developed view of the cam ring, showing a state where a set of front cam followers of the second

lens group moving frame pass through the points of intersection between a set of front inner cam grooves and a set of rear inner cam grooves of the cam ring;

Figure 84 is a perspective view of a portion of the  
5 zoom lens shown in Figures 5 through 10 which includes the second lens group moving frame, the second linear guide ring, a shutter unit and other elements, viewed obliquely from the front thereof;

Figure 85 is a perspective view of the portion of  
10 the zoom lens in Figure 84, viewed obliquely from behind;

Figure 86 is a view similar to that of Figure 84, showing the positional relationship between the second lens group moving frame and the second linear guide ring when the second lens group moving frame is positioned at  
15 its front limit for the axial movement thereof with respect to the second linear guide ring;

Figure 87 is a perspective view of the portion of the zoom lens in Figure 86, viewed obliquely from behind;

Figure 88 is a front elevational view of the second  
20 linear guide ring;

Figure 89 is a rear elevational view of the second lens group moving frame, the second linear guide ring and other elements in an assembled state thereof;

Figure 90 is a developed view of the first external  
25 barrel and the cam ring in relation to a set of cam

followers of the first external barrel, showing the positional relationship between the first external barrel and the cam ring in the retracted state of the zoom lens;

5       Figure 91 is a view similar to that of Figure 90, showing a state where each cam follower of the first external barrel is positioned at the insertion end of the inclined lead section of the associated outer cam groove of a set of outer cam grooves of the cam ring by a rotation  
10      of the cam ring in a lens barrel advancing direction thereof;

Figure 92 is a view similar to that of Figure 90, showing the positional relationship between the first external barrel and the cam ring at the wide-angle  
15      extremity of the zoom lens;

Figure 93 is a view similar to that of Figure 90, showing the positional relationship between the first external barrel and the cam ring at the telephoto extremity of the zoom lens;

20      Figure 94 is a view similar to that of Figure 90, showing a positional relationship between the first external barrel and the cam ring;

Figure 95 is a magnified view of a part of the drawing shown in Figure 90;

25      Figure 96 is a magnified view of a part of the drawing

shown in Figure 91;

Figure 97 is view similar to those of Figures 95 and 96, showing a state where each cam follower of the first external barrel are positioned in the inclined lead 5 section of the associated outer cam groove of the cam ring;

Figure 98 is a magnified view of a part of the drawing shown in Figure 92;

Figure 99 is a magnified view of a part of the drawing shown in Figure 93;

10 Figure 100 is a magnified view of a part of the drawing shown in Figure 94;

Figure 101 is a view similar to that of Figure 95, showing another embodiment of the structure of the set of outer cam grooves of the cam ring, showing the 15 positional relationship between the first external barrel and the cam ring in the retracted state of the zoom lens;

Figure 102 is an exploded perspective view of a structure of the zoom lens for supporting a second lens 20 frame which holds the second lens group, for retracting the second lens frame to a radially retracted position thereof, and for adjusting the position of the second lens frame;

Figure 103 is a perspective view of the structure 25 for the second lens frame shown in Figure 102 in an

assembled state and a position-control cam bar of a CCD holder, viewed obliquely from the front;

Figure 104 is a perspective view of the structure for the second lens frame and the position-control cam bar shown in Figure 103, viewed obliquely from behind;

Figure 105 is a view similar to that of Figure 104, showing a state where the position-control cam bar is in the process of entering the cam-bar insertable hole of a rear second lens frame support plate fixed to the second lens group moving frame;

Figure 106 is a front elevational view of the second lens group moving frame;

Figure 107 is a perspective view of the second lens group moving frame;

Figure 108 is a perspective view of the second lens group moving frame and the shutter unit fixed thereto, viewed obliquely from front;

Figure 109 is a perspective view of the second lens group moving frame and the shutter unit shown in Figure 108, viewed obliquely from behind;

Figure 110 is a front elevational view of the second lens group moving frame and the shutter unit shown in Figure 108;

Figure 111 is a rear elevational view of the second lens group moving frame and the shutter unit shown in

**Figure 108;**

Figure 112 is a view similar to that of Figure 111, showing a state where the second lens frame has retracted to the radially retracted position;

5       Figure 113 is a cross sectional view taken along M3-M3 line shown in Figure 110;

Figure 114 is a front elevational view of the structure for the second lens frame shown in Figures 105 and 108 through 112, showing a state where the second lens  
10 frame is held at a photographing position thereof as shown in Figure 110;

Figure 115 is a front elevational view of a portion of the structure for the second lens frame shown in Figure 114;

15       Figure 116 is a view similar to that of Figure 115 in a different state;

Figure 117 is a front elevational view of a portion of the structure for the second lens frame shown in Figures 105 and 108 through 116;

20       Figure 118 is a front elevational view of a portion of the structure for the second lens frame shown in Figures 105 and 108 through 116, showing the positional relationship between the second lens frame and the position-control cam bar of the CCD holder when the second  
25 lens frame is held in a photographing position thereof

as shown in Figures 109 and 111;

Figure 119 is a view similar to that of Figure 118, showing a positional relationship between the second lens frame and the position-control cam bar of the CCD holder;

5       Figure 120 is a view similar to that of 118, showing the positional relationship between the second lens frame and the position-control cam bar of the CCD holder when the second lens frame is held in the radially retracted position as shown in Figure 112;

10      Figure 121 is a perspective view of an AF lens frame and the CCD holder shown in Figures 1 and 4, showing a state where the AF lens frame is fully retracted to contact with and the CCD holder, viewed obliquely from lower front of the CCD holder;

15      Figure 122 is a front elevational view of the CCD holder, the AF lens frame and the second lens group moving frame;

20      Figure 123 is a perspective view of the CCD holder, the AF lens frame, the second lens group moving frame, the second lens frame and other elements;

Figure 124 is a view similar to that of Figure 123, showing a state where the second lens frame has fully moved rearward and fully rotated to the radially retracted position;

25      Figure 125 is an axial cross sectional view of a

portion of the upper half of the zoom lens shown in Figure 9, showing a structure wiring a flexible PWB for exposure control in the zoom lens;

Figure 126 is a perspective view of the second lens frame, the flexible PWB and other elements, showing a manner of supporting the flexible PWB by the second lens frame;

Figure 127 is a perspective view of the second lens frame and the AF lens frame, showing a state where the second lens frame has retracted closely to the AF lens frame;

Figure 128 is a side elevational view of the second lens frame and the AF lens frame, showing a state immediately before the second lens frame comes into contact with the AF lens frame;

Figure 129 is a view similar to that of Figure 128, showing a state where the second lens frame is in contact with the AF lens frame;

Figure 130 is a front elevational view of the second lens frame and the AF lens frame, showing a positional relationship therebetween;

Figure 131 is a perspective view of the first external barrel that surrounds the second lens group moving frame, and the first lens frame for the first lens group that is held by the first external barrel;

Figure 132 is a front elevational view of the first external barrel and the first lens frame;

Figure 133 is a perspective view of the first lens frame, the second lens group moving frame, the AF lens frame and the shutter unit, viewed obliquely from front, showing the positional relationship thereamong at a ready-to-photograph state of the zoom lens;

Figure 134 is a perspective view of the first lens frame, the second lens group moving frame, the AF lens frame and the shutter unit which are shown in Figure 133, viewed obliquely from rear thereof;

Figure 135 is a view similar to that of Figure 133, showing the positional relationship among the first lens frame, the second lens group moving frame, the AF lens frame and the shutter unit, showing the positional relationship thereamong in the retracted state of the zoom lens;

Figure 136 is a perspective view of the first lens frame, the second lens group moving frame, the AF lens frame and the shutter unit which are shown in Figure 135, viewed obliquely from rear thereof;

Figure 137 is a rear elevational view of the first lens frame, the second lens group moving frame, the AF lens frame and the shutter unit which are shown in Figure 135;

Figure 138 is a perspective view, of the first lens frame, the first external barrel, the second lens group moving frame, the AF lens frame and the shutter unit in the retracted state of the zoom lens, showing the 5 positional relationship thereamong in the retracted state of the zoom lens;

Figure 139 is a front elevational view of the first lens frame, the first external barrel, the second lens group moving frame, the AF lens frame and the shutter unit 10 which are shown in Figure 138;

Figure 140 is an exploded perspective view of the shutter unit of the zoom lens;

Figure 141 is a longitudinal cross sectional view of a portion of the zoom lens in the vicinity of the first 15 lens group in the upper half of the zoom lens shown in Figure 9, in which the zoom lens is in a ready-to-photograph state;

Figure 142 is a view similar to that of Figure 141 and shows the same portion in the upper half of the zoom 20 lens shown in Figure 10, in which the zoom lens is in the retracted state;

Figure 143 is an exploded perspective view of the viewfinder unit shown in Figures 5 through 8;

Figure 144 is a developed view, similar to that of 25 Figure 23, of the helicoid ring and the third external

barrel in relation to a zoom gear and a viewfinder drive gear, showing the positional relationship thereamong in the retracted state of the zoom lens;

Figure 145 is a developed view, similar to that of  
5 Figure 24, of the helicoid ring and the stationary barrel in relation to the zoom gear and the viewfinder drive gear, showing the positional relationship thereamong at the wide-angle extremity the zoom lens;

Figure 146 is a perspective view of a power  
10 transmission system of the zoom lens for imparting rotation of a zoom motor from the helicoid ring to movable lenses of a viewfinder optical system incorporated in the viewfinder unit;

Figure 147 is a front elevational view of the power  
15 transmission system shown in Figure 148;

Figure 148 is a side elevational view of the power transmission system shown in Figure 148;

Figure 149 is an enlarged developed view of the helicoid ring and the viewfinder drive gear, showing a  
20 positional relationship therebetween in the middle of rotation of the helicoid ring in the lens barrel advancing direction from the retracted position shown in Figure 144 to the wide-angle extremity shown in Figure 145.

Figure 150 is a view similar to that of Figure 149,  
25 showing a state subsequent to the state shown in Figure

149;

Figure 151 is a view similar to that of Figure 149,  
showing a state subsequent to the state shown in Figure  
150;

5       Figure 152 is a view similar to that of Figure 149,  
showing a state subsequent to the state shown in Figure  
151;

10      Figure 153 is a front elevational view of the  
helicoid ring and the viewfinder drive gear which are  
shown in Figure 150;

Figure 154 is a front elevational view of the  
helicoid ring and the viewfinder drive gear which are  
shown in Figure 151;

15      Figure 155 is a front elevational view of the  
helicoid ring and the viewfinder drive gear which are  
shown in Figure 152;

Figure 156 is a developed view of a cam-incorporated  
gear of the viewfinder unit;

20      Figure 157 is a developed view, similar to that of  
Figure 156, of a comparative example of a cam-incorporated  
gear incorporating an idle running section which is to  
be compared with the cam-incorporated gear shown in Figure  
156; and

25      Figure 158 is an alternative embodiment of that  
shown in Figure 113.

#### DESCRIPTION OF THE PREFERRED EMBODIMENT

In some of the drawings, lines of different thicknesses and/or different types of lines are used as  
5 the outlines of different elements for the purpose of illustration. Additionally, in some cross sectional drawings, several elements are shown on a common plane, though positioned in different circumferential positions, for the purpose of illustration.

10 In Figure 22, the symbols "(S)", "(L)", "(R)" and "(RL)" which are each appended as a suffix to the reference numeral of some elements of a present embodiment of a zoom lens (zoom lens barrel) 71 (see Figures 5 through 10) indicate that the element is stationary, the element is  
15 solely movable linearly along a lens barrel axis Z0 (see Figures 9 and 10) without rotating about the lens barrel axis Z0, the element is rotatable about the lens barrel axis Z0 without moving along the lens barrel axis Z0, and the element is solely movable along the lens barrel axis  
20 Z0 while rotating about the lens barrel axis Z0, respectively. Additionally, in Figure 22, the symbol "(R,  
RL)" which is appended as a suffix to the reference numeral of some elements of the zoom lens 71 indicates that the element rotates about the lens barrel axis Z0 without  
25 moving along the lens barrel axis Z0 during a zooming

operation and that the element moves along the lens barrel axis Z0 while rotating about the lens barrel axis Z0 during the time the zoom lens 71 advances from or retracts into a camera body 72 upon power being turned ON or OFF, while 5 the symbol "(S, L)" which is appended as a suffix to the reference numeral of some elements of the zoom lens 71 indicates that the element is stationary when the zoom lens 71 in a zooming range in which a zooming operation is possible and that the element moves linearly along the 10 lens barrel axis Z0 without rotating about the lens barrel axis Z0 during the time the zoom lens 71 advances from or retracts into the camera body 72 upon power being turned ON or OFF.

As shown in Figures 9 and 10, the present embodiment 15 of the zoom lens 71 incorporated in a digital camera 70 is provided with a photographing optical system consisting of a first lens group LG1, a shutter S, an adjustable diaphragm A, a second lens group LG2, a third lens group LG3, a low-pass filter (optical filter) LG4, 20 and a CCD image sensor (solid-state image pick-up device) 60. "Z1" shown in Figures 9 and 10 designates the optical axis of the photographing optical system. The photographing optical axis Z1 is parallel to a common rotational axis (the lens barrel axis Z0) of external 25 barrels which form an outward appearance of the zoom lens

71. Moreover, the photographing optical axis Z1 is positioned below the lens barrel axis Z0. The first lens group LG1 and the second lens group LG2 are driven along the photographing optical axis Z1 in a predetermined 5 moving manner to perform a zooming operation, while the third lens group L3 is driven along the photographing optical axis Z1 to perform a focusing operation. In the following descriptions, the term "optical axis direction" means a direction parallel to the 10 photographing optical axis Z1 unless there is a different explanatory note on the expression.

As shown in Figures 9 and 10, the camera 70 is provided in the camera body 72 thereof with a stationary barrel 22 fixed to the camera body 72, and a CCD holder 15 21 fixed to a rear portion of the stationary barrel 22. The CCD image sensor 60 is mounted to the CCD holder 21 to be held thereby via a CCD base plate 62. The low-pass filter LG4 is held by the CCD holder 21 to be positioned in front of the CCD 60 via a filter holder 20 portion 21b and an annular sealing member 61. The filter holder portion 21b is a portion formed integrally with the CCD holder 21. The camera 70 is provided behind the CCD holder 21 with an LCD panel 20 which indicates a live image so that the user can see how the image about to be 25 taken looks before photographing, captured images so that

the user can review pictures which he or she has already taken, and also various photographing information.

The zoom lens 71 is provided in the stationary barrel 22 with an AF lens frame (a third lens frame which supports 5 and holds the third lens group LG3) 51 which is guided linearly in the optical axis direction without rotating about the photographing optical axis Z1. Specifically, the zoom lens 71 is provided with a pair of AF guide shafts 52 and 53 which extend parallel to the photographing 10 optical axis Z1 to guide the AF lens frame 51 in the optical axis direction without rotating the AF lens frame 51 about the photographing optical axis Z1. Front and rear ends of each guide shaft of the pair of AF guide shafts 52 and 15 53 are fixed to the stationary barrel 22 and the CCD holder 21, respectively. The AF lens frame 51 is provided on radially opposite sides thereof with a pair of guide holes 51a and 51b in which the pair of AF guide shafts 52 and 53 are respectively fitted so that the AF lens frame 51 is slidable on the pair of AF guide shafts 52 and 53. In 20 this particular embodiment, the amount of clearance between the AF guide shaft 53 and the guide hole 51b is greater than that between the AF guide shaft 52 and the guide hole 51a. Namely, the AF guide shaft 52 serves as a main guide shaft for achieving a great positioning 25 accuracy, while the AF guide shaft 53 serves as an

auxiliary guide shaft. The camera 70 is provided with an AF motor 160 (see Figure 1) having a rotary drive shaft which is threaded to serve as a feed screw shaft, and this rotary drive shaft is screwed through a screw hole formed 5 on an AF nut 54 (see Figure 1). The AF nut 54 is provided with a rotation-preventing protrusion 54a. The AF lens frame 51 is provided with a guide groove 51m (see Figure 127), extending in a direction parallel to the optical axis Z1, in which the rotation-preventing protrusion 54a 10 is slidably fitted. Furthermore, the AF lens frame 51 is provided with a stopper protrusion 51n (see Figure 127) which is positioned behind the AF nut 54. The AF lens frame 51 is biased forward in the optical axis direction by an extension coil spring 55 serving as a biasing member, 15 and the forward movement limit of the AF lens frame 51 is determined via engagement between the stopper protrusion 51n and the AF nut 54. The AF lens frame 51 can be moved rearward against the biasing force of the extension coil spring 55 when a rearward force is applied 20 by the AF nut 54. Due to this structure, rotating the rotary drive shaft of AF motor 160 forward and rearward causes the AF lens frame 51 to move forward and rearward in the optical axis direction. In addition, the AF lens frame 51 can be moved rearward against the biasing force 25 of the extension coil spring 55 when a rearward force is

directly applied to the AF lens frame 51.

As shown in Figures 5 and 6, the camera 70 is provided above the stationary barrel 22 with a zoom motor 150 and a reduction gear train box 74 which are mounted on the 5 stationary barrel 22. The reduction gear train box 74 contains a reduction gear train for transferring rotation of the zoom motor 150 to a zoom gear 28 (see Figure 4). The zoom gear 28 is rotatably fitted on a zoom gear shaft 29 extending parallel to the photographing optical axis 10 Z1. Front and rear ends of the zoom gear shaft 29 are fixed to the stationary barrel 22 and the CCD holder 21, respectively. Rotations of the zoom motor 150 and the AF motor 160 are controlled by a control circuit 140 (see Figure 22) via a flexible PWB (printed wiring board) 75 15 which is partly positioned on an outer peripheral surface of the stationary barrel 22. The control circuit 140 comprehensively controls the overall operation of the camera 70.

As shown in Figure 4, the stationary barrel 22 is 20 provided on an inner peripheral surface thereof with a female helicoid 22a, a set of three linear guide grooves 22b, a set of three inclined grooves 22c, and a set of three rotational sliding grooves 22d. Threads of the female helicoid 22a extend in a direction inclined with 25 respect to both the optical axis direction and a

circumferential direction of the stationary barrel 22. The set of three linear guide grooves 22b extend parallel to the photographing optical axis Z1. The set of three inclined grooves 22c extend parallel to the female 5 helicoid 22a. The set of three rotational sliding grooves 22d are formed in the vicinity of a front end of the inner peripheral surface of the stationary barrel 22 to extend along a circumference of the stationary barrel 22 to communicate the front ends of the set of three 10 inclined grooves 22c, respectively. The female helicoid 22a is not formed on that specific front area (non-helicoid area 22z) of the inner peripheral surface of the stationary barrel 22 which is positioned immediately behind the set of three rotational sliding grooves 22d 15 (see Figures 11, 23 through 26).

The zoom lens 71 is provided in the stationary barrel 22 with a helicoid ring 18. The helicoid ring 18 is provided on an outer peripheral surface thereof with a male helicoid 18a and a set of three rotational sliding 20 projections 18b. The male helicoid 18a is engaged with the female helicoid 22a, and the set of three rotational sliding projections 18b are engaged in the set of three inclined grooves 22c or the set of three rotational sliding grooves 22d, respectively (see Figures 4 and 12). 25 The helicoid ring 18 is provided on threads of the male

helicoid 18a with an annular gear 18c which is in mesh with the zoom gear 28. Therefore, when a rotation of the zoom gear 28 is transferred to the annular gear 18c, the helicoid ring 18 moves forward or rearward in the optical axis direction while rotating about the lens barrel axis Z0 within a predetermined range in which the male helicoid 18a remains in mesh with the female helicoid 22a. A forward movement of the helicoid ring 18 beyond a predetermined point with respect to the stationary barrel 22 causes the male helicoid 18a to be disengaged from the female helicoid 22a so that the helicoid ring 18 rotates about the lens barrel axis Z0 without moving in the optical axis direction relative to the stationary barrel 22 by engagement of the set of three rotational sliding projections 18b with the set of three rotational sliding grooves 22d.

The set of three inclined grooves 22c are formed on the stationary barrel 22 to prevent the set of three rotational sliding projections 18b and the stationary barrel 22 from interfering with each other when the female helicoid 22a and the male helicoid 18a are engaged with each other. To this end, each inclined groove 22c is formed on an inner peripheral surface of the stationary barrel 22 to be positioned radially outwards (upwards as viewed in Figure 31) from the bottom of the female helicoid

22a as shown in Figure 31. A circumferential space between two adjacent threads of the female helicoid 22a between which one of the three inclined grooves 22c is positioned is greater than that between another two 5 adjacent threads of the female helicoid 22a between which none of the three inclined grooves 22c is positioned. The male helicoid 18a includes three wide threads 18a-W and twelve narrow threads. The three wide threads 18a-W are positioned behind the three rotational sliding 10 projections 18b in the optical axis direction, respectively (see Figure 12). The circumferential width of each of the three wide threads 18a-W is greater than that of each of the twelve narrow threads so that each 15 of the three wide threads 18a-W can be positioned in the associated two adjacent threads of the female helicoid 22a between which one of the three inclined grooves 22c is positioned (see Figures 11 and 12).

The stationary barrel 22 is provided with a stop-member insertion hole 22e which radially penetrates 20 through the stationary barrel 22. A stop member 26 having a stop projection 26b is fixed to the stationary barrel 22 by a set screw 67 so that the stop projection 26b can be inserted into and removed from the stop-member insertion hole 22e (see Figures 40 and 41).

25 As will be appreciated from Figures 9 and 10, the

zoom lens 71 of the camera 70 is of a telescoping type having three external telescoping barrels: a first external barrel 12, a second external barrel 13 and a third external barrel 15 which are concentrically arranged about the lens barrel axis Z0. The helicoid ring 18 is provided, on an inner peripheral surface thereof at three different circumferential positions on the helicoid ring 18, with three rotation transfer recesses 18d (see Figures 4 and 13) front ends of which are open at the front end of the helicoid ring 18, while the third external barrel 15 is provided, at corresponding three different circumferential positions on the third external barrel 15, with three pairs of rotation transfer projections 15a (see Figures 4 and 14) which project rearward from the rear end of the third external barrel 15 to be inserted into the three rotation transfer recesses 18d from the front thereof, respectively. The three pairs of rotation transfer projections 15a and the three rotation transfer recesses 18d are movable relative to each other in a direction of the lens barrel axis Z0, and are not rotatable relative to each other about the lens barrel axis Z0. Namely, the helicoid ring 18 and the third external barrel 15 rotate in one piece. Strictly speaking, the three pairs of rotation transfer projections 15a and the three rotation transfer recesses 18d are slightly rotatable

relative to each other about the lens barrel axis Z0 by the amount of clearance between the three pairs of rotation transfer projections 15a and the three rotation transfer recesses 18d, respectively. This structure will  
5 be discussed in detail later.

The helicoid ring 18 is provided, on front faces of the three rotational sliding projections 18b at three different circumferential positions on the helicoid ring 18, with a set of three engaging recesses 18e which are  
10 formed on an inner peripheral surface of the helicoid ring 18 to be open at the front end of the helicoid ring 18. The third external barrel 15 is provided, at corresponding three different circumferential positions on the third external barrel 15, with a set of three engaging projections 15b which project rearward from the rear end  
15 of the third external barrel 15, and also project radially outwards, to be engaged in the set of three engaging recesses 18e from the front thereof, respectively. The set of three engaging projections 15b, which are  
20 respectively engaged in the set of three engaging recesses 18e, are also engaged in the set of three rotational sliding grooves 22d at a time, respectively, when the set of three rotational sliding projections 18b are engaged in the set of three rotational sliding grooves 22d (see  
25 Figure 33).

The zoom lens 71 is provided between the third external barrel 15 and the helicoid ring 18 with three compression coil springs 25 which bias the third external barrel 15 and the helicoid ring 18 in opposite directions 5 away from each other in the optical axis direction. The rear ends of the three compression coil springs 25 are respectively inserted into three spring support holes (non-through hole) 18f which are formed on the front end of the helicoid ring 18, while the front ends of the three 10 compression coil springs 25 are respectively in pressing contact with three engaging recesses 15c formed at the rear end of the third external barrel 15. Therefore, the set of three engaging projections 15b of the third external barrel 15 are respectively pressed against front 15 guide surfaces 22d-A (see Figures 28 through 30) of the rotational sliding grooves 22d by the spring force of the three compression coil springs 25. At the same time, the set of three rotational sliding projections 18b of the helicoid ring 18 are respectively pressed against rear 20 guide surfaces 22d-B (see Figures 28 through 30) of the rotational sliding grooves 22d by the spring force of the three compression coil springs 25.

The third external barrel 15 is provided on an inner peripheral surface thereof with a plurality of relative 25 rotation guide projections 15d which are formed at

different circumferential positions on the third external barrel 15, a circumferential groove 15e which extends in a circumferential direction about the lens barrel axis Z0, and a set of three rotation transfer grooves 15f which extend parallel to the lens barrel axis Z0 (see Figures 4 and 14). The plurality of relative rotation guide projections 15d are elongated in a circumferential direction of the third external barrel to lie in a plane orthogonal to the lens barrel axis Z0.

As can be seen in Figure 14, each rotation transfer groove 15f intersects the circumferential groove 15e at right angles. The circumferential positions of the three rotation transfer grooves 15f are formed to correspond to those of the three pairs of rotation transfer projections 15a, respectively. The rear end of each rotation transfer groove 15f is open at the rear end of the third external barrel 15. The helicoid ring 18 is provided on an inner peripheral surface thereof with a circumferential groove 18g which extends in a circumferential direction about the lens barrel axis Z0 (see Figures 4 and 13). The zoom lens 71 is provided inside the third external barrel 15 and the helicoid ring 18 with a first linear guide ring 14. The first linear guide ring 14 is provided on an outer peripheral surface thereof with a set of three linear guide projections 14a,

a first plurality of relative rotation guide projections 14b, a second plurality of relative rotation guide projections 14c, and a circumferential groove 14d in this order from rear to front of the first linear guide ring 14 in the optical axis direction (see Figures 4 and 15). The set of three linear guide projections 14a project radially outwards in the vicinity of the rear end of the first linear guide ring 14. The first plurality of relative rotation guide projections 14b project radially outwards at different circumferential positions on the first linear guide ring 14, and are each elongated in a circumferential direction of the first linear guide ring 14 to lie in a plane orthogonal to the lens barrel axis Z0. Likewise, the second plurality of relative rotation guide projections 14c project at different circumferential positions on the first linear guide ring 14, and are each elongated in a circumferential direction of the first linear guide ring 14 to lie in a plane orthogonal to the lens barrel axis Z0. The circumferential groove 14d is an annular groove with its center on the lens barrel axis Z0. The first linear guide ring 14 is guided in the optical axis direction with respect to the stationary barrel 22 by engagement of the set of three linear guide projections 14a with the set of three linear guide grooves 22b, respectively. The

third external barrel 15 is coupled to the first linear guide ring 14 to be rotatable about the lens barrel axis Z0 relative to the first linear guide ring 14 by both the engagement of the second plurality of relative rotation 5 guide projections 14c with the circumferential groove 15e and the engagement of the plurality of relative rotation guide projections 15d with the circumferential groove 14d. The second plurality of relative rotation guide projections 14c and the circumferential groove 15e are 10 engaged with each other to be slightly movable relative to each other in the optical axis direction. Likewise, the plurality of relative rotation guide projections 15d and the circumferential groove 14d are engaged with each other to be slightly movable relative to each other in 15 the optical axis direction. The helicoid ring 18 is coupled to the first linear guide ring 14 to be rotatable about the lens barrel axis Z0 relative to the first linear guide ring 14 by engagement of the first plurality of relative rotation guide projections 14b with the 20 circumferential groove 18g. The first plurality of relative rotation guide projections 14b and the circumferential groove 18g are engaged with each other to be slightly movable relative to each other in the optical axis direction.

25           The first linear guide ring 14 is provided with a

set of three through-slots 14e which radially penetrate the first linear guide ring 14. As shown in Figure 15, each through-slot 14e includes a front circumferential slot portion 14e-1, a rear circumferential slot portion 5 14e-2, and an inclined lead slot portion 14e-3 which connects the front circumferential slot portion 14e-1 with the rear circumferential slot portion 14e-2. The front circumferential slot portion 14e-1 and the rear circumferential slot portion 14e-2 extend parallel to 10 each other in a circumferential direction of the first linear guide ring 14. The zoom lens 71 is provided with a cam ring 11 a front portion of which is positioned inside the first external barrel 12. A set of three roller followers 32 fixed to an outer peripheral surface of the 15 cam ring 11 at different circumferential positions thereon are engaged in the set of three through-slots 14e, respectively (see Figure 3). Each roller follower 32 is fixed to the cam ring 11 by set screw 32a. The set of three roller followers 32 are further engaged in the set 20 of three rotation transfer grooves 15f through the set of three through-slots 14e, respectively. The zoom lens 71 is provided between the first linear guide ring 14 and the third external barrel 15 with a follower-biasing ring spring 17. A set of three follower pressing protrusions 25 17a protrude rearward from the follower-biasing ring

spring 17 to be engaged in front portions of the set of three rotation transfer grooves 15f, respectively (see Figure 14). The set of three follower pressing protrusions 17a press the set of three roller followers 32 rearward to remove backlash between the set of three roller followers 32 and the set of three through-slots 14e when the set of three roller followers 32 are engaged in the front circumferential slot portions 14e-1 of the set of three through-slots 14e, respectively.

Advancing operations of movable elements of the zoom lens 71 from the stationary barrel 22 to the cam ring 11 will be discussed hereinafter with reference to the above described structure of the digital camera 70. Rotating the zoom gear 28 in a lens barrel advancing direction by the zoom motor 150 causes the helicoid ring 18 to move forward while rotating about the lens barrel axis Z0 due to engagement of the female helicoid 22a with the male helicoid 18a. This rotation of the helicoid ring 18 causes the third external barrel 15 to move forward together with the helicoid ring 18 while rotating about the lens barrel axis Z0 together with the helicoid ring 18, and further causes the first linear guide ring 14 to move forward together with the helicoid ring 18 and the third external barrel 15 because each of the helicoid ring 18 and the third external barrel 15 is coupled to the first

linear guide ring 14 to make respective relative rotations between the third external barrel 15 and the first linear guide ring 14 and between the helicoid ring 18 and the first linear guide ring 14 possible and to be movable 5 together along a direction of a common rotational axis (i.e., the lens barrel axis Z0) due to the engagement of the first plurality of relative rotation guide projections 14b with the circumferential groove 18g, the engagement of the second plurality of relative rotation 10 guide projections 14c with the circumferential groove 15e and the engagement of the plurality of relative rotation guide projections 15d with the circumferential groove 14d. Rotation of the third external barrel 15 is transferred to the cam ring 11 via the set of three rotation transfer 15 grooves 15f and the set of three roller followers 32, which are engaged in the set of three rotation transfer grooves 15f, respectively. Since the set of three roller followers 32 are also engaged in the set of three through-slots 14e, respectively, the cam ring 11 moves 20 forward while rotating about the lens barrel axis Z0 relative to the first linear guide ring 14 in accordance with contours of the lead slot portions 14e-3 of the set of three through-slots 14e. Since the first linear guide ring 14 itself moves forward together with the third lens 25 barrel 15 and the helicoid ring 18 as described above,

the cam ring 11 moves forward in the optical axis direction by an amount of movement corresponding to the sum of the amount of the forward movement of the first linear guide ring 14 and the amount of the forward movement of the cam 5 ring 11 by engagement of the set of three roller followers 32 with the lead slot portions 14e-3 of the set of three through-slots 14e, respectively.

The above described rotating-advancing operations of the cam ring 11, the third external barrel 15 and the 10 helicoid ring 18 are performed while the set of three rotational sliding projections 18b are moving in the set of three inclined grooves 22c, respectively, only when the male helicoid 18a and the female helicoid 22a are engaged with each other. When the helicoid ring 18 moves 15 forward by a predetermined amount of movement, the male helicoid 18a and the female helicoid 22a are disengaged from each other so that the set of three rotational sliding projections 18b move from the set of three inclined grooves 22c to the set of three rotational sliding grooves 20 22d, respectively. Since the helicoid ring 18 does not move in the optical axis direction relative to the stationary barrel 22 even if rotating upon the disengagement of the male helicoid 18a from the female helicoid 22a, the helicoid ring 18 and the third external 25 barrel 15 rotate at respective axial fixed positions

thereof without moving in the optical axis direction due to the engagement of the set of three rotational sliding projections 18b with the set of three rotational sliding grooves 22d. Furthermore, at substantially the same time 5 when the set of three rotational sliding projections 18b slide into the set of three rotational sliding grooves 22d from the set of three inclined grooves 22c, respectively, the set of three roller followers 32 enter the front circumferential slot portions 14e-1 of the set 10 of three through-slots 14e, respectively. In this state, since the first linear guide ring 14 stops while the set of three roller followers 32 have respectively moved into the front circumferential slot portions 14e-1, the cam ring 11 is not given any force to make the cam ring 11 15 move forward. Consequently, the cam ring 11 only rotates at an axial fixed position in accordance with rotation of the third external barrel 15.

Rotating the zoom gear 28 in a lens barrel retracting direction thereof by the zoom motor 150 causes the 20 aforementioned movable elements of the zoom lens 71 from the stationary barrel 22 to the cam ring 11 to operate in the reverse manner to the above described advancing operations. In this reverse operation, the above described movable elements of the zoom lens 71 retract 25 to their respective retracted positions shown in Figure

10 by rotation of the helicoid ring 18 until the set of three roller followers 32 enter the rear circumferential slot portions 14e-2 of the set of three through-slots 14e, respectively.

5       The first linear guide ring 14 is provided on an inner peripheral surface thereof with a set of three pairs of first linear guide grooves 14f which are formed at different circumferential positions to extend parallel to the photographing optical axis Z1, and a set of six  
10 second linear guide grooves 14g which are formed at different circumferential positions to extend parallel to the photographing optical axis Z1. Each pair of first linear guide grooves 14f are positioned on the opposite sides of the associated linear guide groove 14g (every  
15 other linear guide groove 14g) in a circumferential direction of the first linear guide ring 14. The zoom lens 71 is provided inside the first linear guide ring 14 with a second linear guide ring 10. The second linear guide ring 10 is provided on an outer edge thereof with  
20 a set of three bifurcated projections 10a which project radially outwards from a ring portion 10b of the second linear guide ring 10. Each bifurcated projection 10a is provided at a radially outer end thereof with a pair of radial projections which are respectively engaged in the  
25 associated pair of first linear guide grooves 14f (see

Figures 3 and 18). On the other hand, a set of six radial projections 13a which are formed on an outer peripheral surface of the second external barrel 13 at a rear end thereof to project radially outwards (see Figure 3) are 5 engaged in the set of six second linear guide grooves 14g, respectively to be slidable therealong. Therefore, each of the second external barrel 13 and the second linear guide ring 10 is guided in the optical axis direction via the first linear guide ring 14.

10 The zoom lens 71 is provided inside the cam ring 11 with a second lens group moving frame 8 which indirectly supports and holds the second lens group LG2 (see Figure 3). The first external barrel 12 indirectly supports the first lens group LG1, and is positioned inside the second 15 external barrel 13 (see Figure 2). The second linear guide ring 10 serves as a linear guide member for guiding the second lens group moving frame 8 linearly without rotating the same, while the second external barrel 13 serves as a linear guide member for guiding the first 20 external barrel 12 linearly without rotating the same.

The second linear guide ring 10 is provided on the ring portion 10b with a set of three linear guide keys 10c (specifically two narrow linear guide keys 10c and a wide linear guide key 10c-W) which project forward in 25 parallel to one another (see Figures 3 and 18) from the

ring portion 10b. The second lens group moving frame 8 is provided with a corresponding set of three guide grooves 8a (specifically two narrow guide grooves 8a and a wide guide groove 8a-W) in which the set of three linear 5 guide keys 10c are engaged, respectively. As shown in Figures 9 and 10, a discontinuous outer edge of the ring portion 10b is engaged in a discontinuous circumferential groove 11e formed on an inner peripheral surface of the cam ring 11 at the rear end thereof to be rotatable about 10 the lens barrel axis Z0 relative to the cam ring 11 and to be immovable relative to the cam ring 11 in the optical axis direction. The set of three linear guide keys 10c project forward from the ring portion 10b to be positioned inside the cam ring 11. Opposite edges of each linear 15 guide key 10c in a circumferential direction of the second linear guide ring 10 serve as parallel guide edges which are respectively engaged with circumferentially-opposed guide surfaces in the associated guide groove 8a of the second lens group moving frame 8, which is positioned in 20 the cam ring 11 to be supported thereby, to guide the second lens group moving frame 8 linearly in the optical axis direction without rotating the same about the lens barrel axis Z0.

The wide linear guide key 10c-W has a 25 circumferential width greater than those of the other two

linear guide keys 10c to also serve as a support member for supporting a flexible PWB (printed wiring board) 77 (see Figures 84 through 87) used for exposure control. The wide linear guide key 10c-W is provided thereon with

5 a radial through hole 10d through which the flexible PWB 77 passes (see Figure 18). A portion of the ring portion 10b from which the wide linear guide key 10c-W projects forward is partly cut out so that the rear end of the radial through hole 10d extends through the rear end of the ring portion 10b. As shown in Figures 9 and 125, the flexible

10 PWB 77 for exposure control passes through the radial through hole 10d to extend forward along an outer surface of the wide linear guide key 10c-W from the rear of the ring portion 10b, and subsequently bends radially inwards

15 in the vicinity of the front end of the wide linear guide key 10c-W to extend rearward along an inner surface of the wide linear guide key 10c-W. The wide guide groove 8a-W has a circumferential width greater than those of the other two guide grooves 8a so that the wide linear

20 guide key 10c-W can be engaged in the wide guide groove 8a-W to be slidable therealong. As can be clearly seen in Figure 19, the second lens group moving frame 8 is provided in the wide guide groove 8a-W with a radial recess 8a-Wa in which the flexible PWB 77 can lie and two separate

25 bottom walls 8a-Wb positioned on opposite sides of the

radial recess 8a-Wa to support the wide linear guide key 10c-W thereon. Whereas, each of the other two guide grooves 8a is formed as a simple bottomed groove that is formed on an outer peripheral surface of the second lens group moving frame 8. The second lens group moving frame 8 and the second linear guide ring 10 can be coupled to each other only when the wide linear guide key 10c-W and the wide guide groove 8a-W are aligned in the direction of the lens barrel axis Z0.

The cam ring 11 is provided on an inner peripheral surface thereof with a plurality of inner cam grooves 11a for moving the second lens group LG2. As shown in Figure 17, the plurality of inner cam grooves 11a are composed of a set of three front inner cam grooves 11a-1 formed at different circumferential positions, and a set of three rear inner cam grooves 11a-2 formed at different circumferential positions behind the set of three front inner cam grooves 11a-1. Each rear inner cam groove 11a-2 is formed on the cam ring 11 as a discontinuous cam groove (see Figure 17), the detail thereof will be discussed later.

The second lens group moving frame 8 is provided on an outer peripheral surface thereof with a plurality of cam followers 8b. As shown in Figure 19, the plurality of cam followers 8b include a set of three front cam

followers 8b-1 which are formed at different circumferential positions to be respectively engaged in the set of three front inner cam grooves 11a-1, and a set of three rear cam followers 8b-2 which are formed at 5 different circumferential positions behind the set of three front cam followers 8b-1 to be respectively engaged in the set of three rear inner cam grooves 11a-2.

A rotation of the cam ring 11 causes the second lens group moving frame 8 to move in the optical axis direction 10 in a predetermined moving manner in accordance with contours of the plurality of inner cam grooves 11a since the second lens group moving frame 8 is guided linearly in the optical axis direction without rotating via the second linear guide ring 10.

15       The zoom lens 71 is provided inside the second lens group moving frame 8 with a second lens frame (radially-retractable lens frame) 6 which supports and holds the second lens group LG2. The second lens frame 6 is pivoted on a pivot shaft 33 front and rear ends of 20 which are supported by front and rear second lens frame support plates (a pair of second lens frame support plates) 36 and 37, respectively (see Figures 3 and 102 through 105). The pair of second lens frame support plates 36 and 37 are fixed to the second lens group moving frame 8 by a set screw 66. The pivot shaft 33 is a

predetermined distance away from the photographing optical axis Z1, and extends parallel to the photographing optical axis Z1. The second lens frame 6 is swingable about the pivot shaft 33 between a photographing position 5 shown in Figure 9 where the optical axis of the second lens group LG2 coincides with the photographing optical axis Z1 and a radially retracted position (retracted away from the optical axis) shown in Figure 10 where the optical axis of the second lens group LG2 is eccentric from the 10 photographing optical axis Z1. A rotation limit shaft 35 which determines the photographing position of the second lens frame 6 is mounted to the second lens group moving frame 8. The second lens frame 6 is biased to rotate in a direction to come into contact with the 15 rotation limit shaft 35 by a front torsion coil spring 39. A compression coil spring 38 is fitted on the pivot shaft 33 to remove backlash of the second lens frame 6 in the optical axis direction.

The second lens frame 6 moves together with the 20 second lens group moving frame 8 in the optical axis direction. The CCD holder 21 is provided on a front surface thereof with a position-control cam bar 21a which projects forward from the CCD holder 21 to be engageable with the second lens frame 6 (see Figure 4). If the second 25 lens group moving frame 8 moves rearward in a retracting

direction to approach the CCD holder 21, a retracting cam surface 21c (see Figure 103) formed on a front end surface of the position-control cam bar 21a comes into contact with a specific portion of the second lens frame 6 to 5 rotate the second lens frame 6 to the radially retracted position.

The second external barrel 13 is provided, on an inner peripheral surface thereof, with a set of three linear guide grooves 13b which are formed at different 10 circumferential positions to extend parallel to one another in the optical axis direction. The first external barrel 12 is provided on an outer peripheral surface at the rear end thereof with a set of three engaging protrusions 12a which are slidably engaged in 15 the set of three linear guide grooves 13b, respectively (see Figures 2, 20 and 21). Accordingly, the first external barrel 12 is guided linearly in the optical axis direction without rotating about the lens barrel axis Z0 via the first linear guide ring 14 and the second external 20 barrel 13. The second external barrel 13 is further provided on an inner peripheral surface thereof in the vicinity of the rear end of the second external barrel 13 with a discontinuous inner flange 13c which extends along a circumference of the second external barrel 13. 25 The cam ring 11 is provided on an outer peripheral surface

thereof a discontinuous circumferential groove 11c in which the discontinuous inner flange 13c is slidably engaged so that the cam ring 11 is rotatable about the lens barrel axis Z0 relative to the second external barrel 13 and so that the second external barrel 13 is immovable in the optical axis direction relative to the cam ring 11. On the other hand, the first external barrel 12 is provided on an inner peripheral surface thereof with a set of three cam followers 31 which projects radially inwards, while the cam ring 11 is provided on an outer peripheral surface thereof with a set of three outer cam grooves 11b (cam grooves for moving the first lens group LG1) in which the set of three cam followers 31 are slidably engaged, respectively.

The zoom lens 71 is provided inside the first external barrel 12 with a first lens frame 1 which is supported by the first external barrel 12 via a first lens group adjustment ring 2. The first lens group LG1 is supported by the first lens frame 1 to be fixed thereto. The first lens frame 1 is provided on an outer peripheral surface thereof with a male screw thread 1a, and the first lens group adjustment ring 2 is provided on an inner peripheral surface thereof with a female screw thread 2a which is engaged with the male screw thread 1a. The axial position of the first lens frame 1 relative to the first

lens group adjustment ring 2 can be adjusted via the male screw thread 1a and the female screw thread 2a. A combination of the first lens frame 1 and the first lens group adjustment ring 2 is positioned inside the first external barrel 12 to be supported thereby and to be movable in the optical axis direction relative to the first external barrel 12. The zoom lens 71 is provided in front of the first external barrel 12 with a fixing ring 3 which is fixed to the first external barrel 12 by two set screws 64 to prevent the first lens group adjustment ring 2 from moving forward and coming off the first external barrel 12.

The zoom lens 71 is provided between the first and second lens groups LG1 and LG2 with a shutter unit 76 including the shutter S and the adjustable diaphragm A (see Figures 1, 9 and 10). The shutter unit 76 is positioned in the second lens group moving frame 8 to be supported thereby. The air-distance between the shutter S and the second lens group LG2 is fixed. Likewise, the air-distance between the diaphragm A and the second lens group LG2 is fixed. The zoom lens 71 is provided in front of the shutter unit 76 with a shutter actuator 131 for driving the shutter S, and is provided behind the shutter unit 76 with a diaphragm actuator 132 for driving the diaphragm A (see Figures 140). The flexible PWB 77

extends from the shutter unit 76 to establish electrical connection between the control circuit 140 and each of the shutter actuator 131 and the diaphragm actuator 132. Note that, in Figure 9, the flexible PWB 77 is shown in 5 a cross sectional view of a lower half portion of the zoom lens 71 below the photographing optical axis Z1 (the zoom lens 71 set at wide-angle extremity) for the purpose of making the relative locations between the flexible PWB 77 and peripheral elements clearly understandable though 10 the flexible PWB 77 is actually disposed only in the space above the photographing optical axis Z1 in the zoom lens 71.

The zoom lens 71 is provided at the front end of the first external barrel 12 with a lens barrier mechanism 15 which automatically closes a front end aperture of the zoom lens 71 when the zoom lens 71 is retracted into the camera body 72 to protect the frontmost lens element of the photographing optical system of the zoom lens 71, i.e. the first lens group LG1, from getting stains and 20 scratches thereon when the digital camera 70 is not in use. As shown in Figures 1, 9 and 10, the lens barrier mechanism is provided with a pair of barrier blades 104 and 105. The pair of barrier blades 104 and 105 are rotatable about two pivots projecting rearward therefrom 25 to be positioned on radially opposite sides of the

photographing optical axis Z1, respectively. The lens barrier mechanism is further provided with a pair of barrier blade biasing springs 106, a barrier blade drive ring 103, a drive ring biasing spring 107 and a barrier 5 blade holding plate 102. The pair of barrier blades 104 and 105 are biased to rotate in opposite directions to be closed by the pair of barrier blade biasing springs 106, respectively. The barrier blade drive ring 103 is rotatable about the lens barrel axis Z0, and is engaged 10 with the pair of barrier blades 104 and 105 to open the pair of barrier blades 104 and 105 when driven to rotate in a predetermined rotational direction. The barrier blade drive ring 103 is biased to rotate in a barrier opening direction to open the pair of barrier blades 104 15 and 105 by the drive ring biasing spring 107. The barrier blade holding plate 102 is positioned between the barrier blade drive ring 103 and the pair of barrier blades 104 and 105. The spring force of the drive ring biasing spring 107 is greater than the spring force of the pair 20 of barrier blade biasing springs 106 so that the barrier blade drive ring 103 is held by the spring force of the drive ring biasing spring 107 in a specific rotational position thereof to open the pair of barrier blades 104 and 105 against the biasing force of the pair of barrier 25 blade biasing springs 106 in the state shown in Figure

9 where the zoom lens 71 has been extended forward to a point in a zooming range (zooming operation performable range) where a zooming operation can be carried out. In the course of the retracting movement of the zoom lens 5 71 to the retracted position shown in Figure 10 from a position in the zooming range, the barrier blade drive ring 103 is forcefully rotated in a barrier closing direction opposite to the aforementioned barrier opening direction by a barrier drive ring pressing surface 11d (see Figures 3 and 16) formed on the cam ring 11. This rotation of the barrier blade drive ring 103 causes the barrier blade drive ring 103 to be disengaged from the pair of barrier blades 104 and 105 so that the pair of barrier blades 104 and 105 are closed by the spring force 10 of the pair of barrier blade biasing springs 106. The 15 zoom lens 71 is provided immediately in front of the lens barrier mechanism with a substantially round lens barrier cover (decorative plate) 101 which covers the front of the lens barrier mechanism.

20 A lens barrel advancing operation and a lens barrel retracting operation of the zoom lens 71 having the above described structure will be discussed hereinafter.

The stage at which the cam ring 11 is driven to advance from the retracted position shown in Figure 10 25 to the position shown in Figure 9 where the cam ring 11

rotates at the axial fixed position without moving in the optical axis direction has been discussed above, and will be briefly discussed hereinafter.

In the state shown in Figure 10 in which the zoom lens 71 is in the retracted state, the zoom lens 71 is fully accommodated in the camera body 72 so that the front face of the zoom lens 71 is substantially flush with the front face of the camera body 72. Rotating the zoom gear 28 in the lens barrel advancing direction by the zoom motor 150 causes a combination of the helicoid ring 18 and the third external barrel 15 to move forward while rotating about the lens barrel axis Z0 due to engagement of the female helicoid 22a with the male helicoid 18a, and further causes the first linear guide ring 14 to move forward together with the helicoid ring 18 and the third external barrel 15. At this time, the cam ring 11 which rotates by rotation of the third external barrel 15 moves forward in the optical axis direction by an amount of movement corresponding to the sum of the amount of the forward movement of the first linear guide ring 14 and the amount of the forward movement of the cam ring 11 by a leading structure between the cam ring 11 and the first linear guide ring 14, i.e., by engagement of the set of three roller followers 32 with the lead slot portions 14e-3 of the set of three through-slots 14e, respectively.

Once the combination of the helicoid ring 18 and the third external barrel 15 advances to a predetermined point, the male helicoid 18a is disengaged from the female helicoid 22a while the set of three roller followers 32 are 5 disengaged from the lead slot portions 14e-3 to enter the front circumferential slot portions 14e-1, respectively. Consequently, each of the helicoid ring 18 and the third external barrel 15 rotates about the lens barrel axis Z0 without moving in the optical axis direction.

10        A rotation of the cam ring 11 causes the second lens group moving frame 8, which is positioned inside the cam ring 11, to move in the optical axis direction with respect to the cam ring 11 in a predetermined moving manner due to the engagement of the set of three front cam followers 15 8b-1 with the set of three front inner cam grooves 11a-1 and the engagement of the set of three rear cam followers 8b-2 with the set of three rear inner cam grooves 11a-2, respectively. In the state shown in Figure 10 in which the zoom lens 71 is in the retracted state, the second lens frame 6, which is positioned inside the second lens group moving frame 8, has rotated about the pivot shaft 33 to be held in the radially retracted position above the photographing optical axis Z1 by the position-control cam bar 21a so that the optical axis of the second lens group LG2 moves from the photographing optical axis Z1

to a retracted optical axis Z2 positioned above the photographing optical axis Z1. In the course of movement of the second lens group moving frame 8 from the retracted position to a position in the zooming range as shown in  
5 Figure 9, the second lens frame 6 is disengaged from the position-control cam bar 21a to rotate about the pivot shaft 33 from the radially retracted position to the photographing position shown in Figure 9 where the optical axis of the second lens group LG2 coincides with the  
10 photographing optical axis Z1 by the spring force of the front torsion coil spring 39. Thereafter, the second lens frame 6 remains to be held in the photographing position until when the zoom lens 71 is retracted into the camera body 72.

15 In addition, a rotation of the cam ring 11 causes the first external barrel 12, which is positioned around the cam ring 11 and guided linearly in the optical axis direction without rotating about the lens barrel axis Z0, to move in the optical axis direction relative to the cam  
20 ring 11 in a predetermined moving manner due to engagement of the set of three cam followers 31 with the set of three outer cam grooves 11b, respectively.

Therefore, an axial position of the first lens group LG1 relative to a picture plane (a light-sensitive surface  
25 of the CCD image sensor 60) when the first lens group LG1

is moved forward from the retracted position is determined by the sum of the amount of forward movement of the cam ring 11 relative to the stationary barrel 22 and the amount of movement of the first external barrel 12 relative to the cam ring 11, while an axial position of the second lens group LG2 relative to the picture plane when the second lens group LG2 is moved forward from the retracted position is determined by the sum of the amount of forward movement of the cam ring 11 relative to the stationary barrel 22 and the amount of movement of the second lens group moving frame 8 relative to the cam ring 11. A zooming operation is carried out by moving the first and second lens groups LG1 and LG2 on the photographing optical axis Z1 while changing the space therebetween.

When the zoom lens 71 is driven to advance from the retracted position shown in Figure 10, the zoom lens 71 firstly goes into a state shown below the photographing lens axis Z1 in Figure 9 in which the zoom lens 71 is set at wide-angle extremity. Subsequently, the zoom lens 71 goes into the state shown above the photographing lens axis Z1 in Figure 9 in which the zoom lens 71 is set at telephoto extremity by a further rotation of the zoom motor 150 in a lens barrel advancing direction thereof. As can be seen from Figure 9, the space between the first and second lens groups LG1 and LG2 when the zoom lens 71

is set at the wide-angle extremity is greater than that when the zoom lens 71 is set at the telephoto extremity. When the zoom lens 71 is set at the telephoto extremity as shown above the photographing lens axis Z1 in Figure 5, the first and second lens groups LG1 and LG2 have moved to approach each other to have some space therebetween which is smaller than the space in the zoom lens 71 set at the wide-angle extremity. This variation of the space between the first and second lens groups LG1 and LG2 for 10 zooming operation is achieved by contours of the plurality of inner cam grooves 11a (11a-1 and 11a-2) and the set of three outer cam grooves 11b. In the zooming range between the wide-angle extremity and the telephoto extremity, the cam ring 11, the third external barrel 15 and the helicoid ring 18 rotate at their respective axial fixed positions, i.e., without moving in the optical axis direction.

When the first through third lens groups LG1, LG2 and LG3 are in the zooming range, a focusing operation 20 is carried out by moving the third lens group L3 along the photographing optical axis Z1 by rotation of the AF motor 160 in accordance with an object distance.

Driving the zoom motor 150 in a lens barrel retracting direction causes the zoom lens 71 to operate 25 in the reverse manner to the above described advancing

operation to fully retract the zoom lens 71 into the camera body 72 as shown in Figure 10. In the course of this retracting movement of the zoom lens 71, the second lens frame 6 rotates about the pivot shaft 33 to the radially 5 retracted position by the position-control cam bar 21a while moving rearward together with the second lens group moving frame 8. When the zoom lens 71 is fully retracted into the camera body 72, the second lens group LG2 is retracted into the space radially outside the space in 10 which the third lens group LG3, the low-pass filter LG4 and the CCD image sensor 60 are retracted as shown in Figure 10, i.e., the second lens group LG2 is radially retracted into an axial range substantially identical to an axial range in the optical axis direction in which the 15 third lens group LG3, the low-pass filter LG4 and the CCD image sensor 60 are positioned. This structure of the camera 70 for retracting the second lens group LG2 in this manner reduces the length of the zoom lens 71 when the zoom lens 71 is fully retracted, thus making it possible 20 to reduce the thickness of the camera body 72 in the optical axis direction, i.e., in the horizontal direction as viewed in Figure 10.

As described above, the helicoid ring 18, the third external barrel 15 and the cam ring 11 move forward while 25 rotating at the stage at which the zoom lens 71 changes

from the retracted state shown in Figure 10 to a ready-to-photograph state shown in Figure 9 (in which the first through third lens groups LG1, LG2 and LG3 remain within the zooming range), whereas the helicoid ring 18,  
5 the third external barrel 15 and the cam ring 11 rotate at the respective axial fixed positions thereof without moving in the optical axis direction when the zoom lens 71 is in the ready-to-photograph state. The third external barrel 15 and the helicoid ring 18 are engaged  
10 with each other to be rotatable together about the lens barrel axis Z0 by making the three pairs of rotation transfer projections 15a inserted into the three rotation transfer recesses 18d, respectively. In this state where the three pairs of rotation transfer projections 15a are  
15 respectively engaged in the three rotation transfer recesses 18d, the set of three engaging projections 15b are respectively engaged in the set of three engaging recesses 18e, which are formed on inner peripheral surfaces of the helicoid ring 18 in three rotational sliding projections 18b, respectively (see Figures 37 and  
20 38). In a state where the relative rotational angle about the lens barrel axis Z0 between the third external barrel 15 and the helicoid ring 18 is such that the three pairs of rotation transfer projections 15a are respectively  
25 engaged in the three rotation transfer recesses 18d and

that the set of three engaging projections 15b are respectively engaged in the set of three engaging recesses 18e, the front ends of the three compression coil springs 25, the rear ends of which are respectively inserted in 5 the three spring support holes 18f on the front end of the helicoid ring 18, are respectively in pressing contact with the three engaging recesses 15c that are formed at the rear end of the third external barrel 15.

Each of the helicoid ring 18 and the third external 10 barrel 15 is coupled to the first linear guide ring 14 to make respective relative rotations between the third external barrel 15 and the first linear guide ring 14 and between the helicoid ring 18 and the first linear guide ring 14 possible due to the engagement of the first 15 plurality of relative rotation guide projections 14b with the circumferential groove 18g, the engagement of the second plurality of relative rotation guide projections 14c with the circumferential groove 15e and the engagement of the plurality of relative rotation guide projections 15d with the circumferential groove 14d. As can be seen 20 in Figures 33 through 36, the second plurality of relative rotation guide projections 14c and the circumferential groove 15e are engaged with each other to be slightly movable relative to each other in the optical axis 25 direction, the plurality of relative rotation guide

projections 15d and the circumferential groove 14d are engaged with each other to be slightly movable relative to each other in the optical axis direction, and the first plurality of relative rotation guide projections 14b and 5 the circumferential groove 18g are engaged with each other to be slightly movable relative to each other in the optical axis direction. Accordingly, the helicoid ring 18 and the third external barrel 15 are slightly movable relative to each other in the optical axis direction even 10 though prevented from being separated totally from each other in the optical axis direction via the first linear guide ring 14. The amount of play (clearance) between the helicoid ring 18 and the first linear guide ring 14 in the optical axis direction is greater than that between 15 the third external barrel 15 and the first linear guide ring 14.

When the third external barrel 15 and the helicoid ring 18 are engaged with each other to be rotatable relative to the first linear guide ring 14, the spaces 20 between the three spring support holes 18f and the three engaging recesses 15c in the optical axis direction are smaller than the free lengths of the three compression coil springs 25 so that the three compression coil springs 25 are compressed and held between opposed end surfaces 25 of the third external barrel 15 and the helicoid ring 18.

The three compression coil springs 25 compressed between the opposed end surfaces of the third external barrel 15 and the helicoid ring 18 bias the third external barrel 15 and the helicoid ring 18 in opposite directions away 5 from each other by the resilience of the three compression coil springs 25, i.e., bias the third external barrel 15 and the helicoid ring 18 forward and rearward in the optical axis direction by the resilience of the three compression coil springs 25, respectively.

10 As shown in Figures 27 through 31, the stationary barrel 22 is provided in each of the three inclined grooves 22c with two opposed inclined surfaces 22c-A and 22c-B which are apart from each other in a circumferential direction of the stationary barrel. The helicoid ring 15 18 is provided, on opposite side edges of each of the three rotational sliding projections 18b in a circumferential direction of the helicoid ring 18, with two circumferential end surfaces 18b-A and 18b-B which face the two opposed inclined surfaces 22c-A and 22c-B in the 20 associated inclined grooves 22c, respectively. Each of the two opposed inclined surfaces 22c-A and 22c-B in each inclined groove 22c extend parallel to threads of the female helicoid 22a. The two circumferential end surfaces 18b-A and 18b-B of each of the three rotational 25 sliding projections 18b are parallel to the two opposed

inclined surfaces 22c-A and 22c-B in the associated inclined groove 22c, respectively. The two circumferential end surfaces 18b-A and 18b-B of each rotational sliding projection 18b are shaped so as not 5 to interfere with the two opposed inclined surfaces 22c-A and 22c-B in the associated inclined groove 22c, respectively. More specifically, when the male helicoid 18a are engaged with the female helicoid 22a, the two opposed inclined surfaces 22c-A and 22c-B in each inclined 10 groove 22c do not hold the associated rotational sliding projection 18b therebetween as shown in Figure 31. In other words, the two opposed inclined surfaces 22c-A and 22c-B in each inclined groove 22c are not engaged with the two circumferential end surfaces 18b-A and 18b-B of 15 the associated rotational sliding projection 18b, respectively, when the male helicoid 18a are engaged with the female helicoid 22a.

One of the three rotational sliding projections 18b is provided on the circumferential end surface 18b-A 20 thereof with an engaging surface 18b-E (see Figures 37, 38, 39, 42 and 43) with which the stop projection 26b of the stop member 26 can be engaged. The engaging surface 18b-E is parallel to the lens barrel axis Z0.

As described above, the stationary barrel 22 is 25 provided in each of the set of three rotational sliding

grooves 22d with two opposed surfaces: the front guide surface 22d-A and the rear guide surface 22d-B which are apart from each other in the optical axis direction to extend parallel to each other. Each of the three 5 rotational sliding projections 18b is provided with a front sliding surface 18b-C and a rear sliding surface 18b-D which extend parallel to each other to be slidable on the front guide surface 22d-A and the rear guide surfaces 22d-B, respectively. As shown in Figures 37 10 through 39, the set of three engaging recesses 18e are respectively formed on front sliding surfaces 18b-C of the three rotational sliding projections 18b of the helicoid ring 18 to be open at the front end of the helicoid ring 18.

15 In the state shown in Figures 23 and 27 in which the zoom lens 71 is in the retracted state, the two circumferential end surfaces 18b-A and 18b-B of each rotational sliding projection 18b are not in contact with the two opposed inclined surfaces 22c-A and 22c-B in each 20 inclined groove 22c though the set of three rotational sliding projections 18b are positioned in the set of three inclined grooves 22c, respectively, as shown in Figure 31. In the retracted state of the zoom lens 71, the male helicoid 18a is engaged with the female helicoid 22a while 25 the set of three rotational sliding projections 18b are

engaged in the set of three inclined grooves 22c, respectively. Therefore, if the helicoid ring 18 is rotated in a lens barrel advancing direction (in an upward direction as viewed in Figure 23) by rotation of the zoom gear 28 that is in mesh with the annular gear 18c of the helicoid ring 18, the helicoid ring 18 moves forward in the optical axis direction (in a leftward direction as viewed in Figure 23) while rotating about the lens barrel axis Z0 due to engagement of the male helicoid 18a with the female helicoid 22a. During this rotating-advancing operation of the helicoid ring 18, the set of three rotational sliding projections 18b do not interfere with the stationary barrel 22 since the set of three rotational sliding projections 18b move in the set of three set of three inclined grooves 22c therealong, respectively.

When the set of three rotational sliding projections 18b are respectively positioned in the set of three set of three inclined grooves 22c, positions of the set of three engaging projections 15b in the optical axis direction are not limited by the set of three inclined grooves 22c, respectively, and also a position of the front sliding surface 18b-C and a position of the rear sliding surface 18b-D of each rotational sliding projection 18b in the optical axis direction are not limited by the associated inclined groove 22c. As shown

in Figures 35 and 36, the third external barrel 15 and the helicoid ring 18, which are biased in opposite directions away from each other by the spring force of the three compression coil springs 25, are slightly apart 5 from each other in the optical axis direction by a distance corresponding to the amount of clearance between the relative rotation guide projections 14b, 14c and 15d and the circumferential grooves 18g, 15e and 14d, respectively, i.e., by a distance corresponding to the 10 sum of the amount of play (clearance) between the helicoid ring 18 and the first linear guide ring 14 in the optical axis direction and the amount of play (clearance) between the third external barrel 15 and the first linear guide ring 14 in the optical axis direction. In this state, 15 the spring force of the three compression coil springs 25 by which the third external barrel 15 and the helicoid ring 18 are biased in opposite directions away from each other is small because the three compression coil springs 25 are not compressed largely, so that the space between 20 the third external barrel 15 and the helicoid ring 18 is loosely maintained. The existence of this loosely maintained space does not become a substantial problem because any pictures are not taken during the translation of the zoom lens 71 from the retracted state to the 25 ready-to-photograph state, i.e., when the set of three

rotational sliding projections 18b are engaged in the set of three inclined grooves 22c. In retractable telescoping type zoom lenses including the preset embodiment of the zoom lens 71, it is generally the case 5 that the total time in which the zoom lens is in the retracted position (including the time when the power is OFF) is greater than the service hours (operating time). Accordingly, it is desirable to apply no heavy load to biasing members such as three compression coil springs 10 25 to prevent the biasing members from deteriorating with time unless the zoom lens is in the ready-to-photograph state. In addition, if the spring force of the three compression coil springs 25 is small, only a little load is applied to the associated moving parts of the zoom lens 15 71 during the translation of the zoom lens 71 from the retracted state to the ready-to-photograph state. This lessens the loads applied to the zoom motor 150.

A forward movement of the helicoid ring 18 in the optical axis direction causes the first linear guide ring 20 14 to move together with the helicoid ring 18 in the optical axis direction due to engagement of the engagement of the first plurality of relative rotation guide projections 14b with the circumferential groove 18g. At the same time, a rotation of the helicoid ring 18 is 25 transferred to the cam ring 11 via the third external

barrel 15 to move the cam ring 11 forward in the optical axis direction while rotating the cam ring 11 about the lens barrel axis Z0 relative to the first linear guide ring 14 by engagement of the set of three roller followers 5 32 with the lead slot portions 14e-3 of the set of three through-slots 14e, respectively. This rotation of the cam ring 11 causes the first lens group LG1 and the second lens group LG2 to move along the photographing optical axis Z1 in a predetermined moving manner in accordance 10 with contours of the set of three outer cam grooves 11b for moving the first lens group LG1 and the plurality of inner cam grooves 11a (11a-1 and 11a-2) for moving the second lens group LG2.

Upon moving beyond the front ends of the set of three 15 inclined grooves 22c, the set of three rotational sliding projections 18b enter the set of three rotational sliding grooves 22d, respectively. The ranges of formation of the male helicoid 18a and the female helicoid 22a on the helicoid ring 18 and the stationary barrel 22, 20 respectively, are determined so that the male helicoid 18a and the female helicoid 22a are disengaged from each other at the time when the set of three rotational sliding projections 18b enter the set of three rotational sliding grooves 22d, respectively. More specifically, the 25 stationary barrel 22 is provided, on an inner peripheral

surface thereof immediately behind the set of three rotational sliding grooves 22d, with the aforementioned non-helicoid area 22z, on which no threads of the female helicoid 22a are formed, and the width of the non-helicoid 5 area 22z in the optical axis direction is greater than the width of that area on the outer peripheral surface of the helicoid ring 18 on which the male helicoid 18 is formed in the optical axis direction. On the other hand, the space between the male helicoid 18a and the set of 10 three rotational sliding projections 18b in the optical axis direction is determined so that the male helicoid 18a and the set of three rotational sliding projections 18b are positioned within the non-helicoid area 22z in the optical axis direction when the set of three 15 rotational sliding projections 18b are positioned in the set of three rotational sliding grooves 22d, respectively. Therefore, at the time when the set of three rotational sliding projections 18b respectively enter the set of three rotational sliding grooves 22d, the male helicoid 20 18a and the female helicoid 22a are disengaged from each other, so that the helicoid ring 18 does not move in the optical axis direction even if rotating about the lens barrel axis Z0 relative to the stationary barrel 22. Thereafter, the helicoid ring 18 rotates about the lens 25 barrel axis Z0 without moving in the optical axis

direction in accordance with rotation of the zoom gear 28 in the lens barrel advancing direction. As shown in Figure 24, the zoom gear 28 remains engaged with the annular gear 18c even after the helicoid ring 18 has moved 5 to the fixed axis position thereof, at which the helicoid ring 18 rotates about the lens barrel axis Z0 without moving in the optical axis direction due to the engagement of the set of three rotational sliding projections 18b with the set of three rotational sliding grooves 22d.

10 This makes it possible to continue to transfer rotation of the zoom gear 28 to the helicoid ring 18.

The state of the zoom lens 71 shown in Figures 24 and 28 in which the helicoid ring 18 can rotate at the axial fixed position while the set of three rotational 15 sliding projections 18b have slightly moved in the set of three rotational sliding grooves 22d corresponds to a state in which the zoom lens 71 is set at the wide-angle extremity. As shown in Figure 28 in which the zoom lens 71 is set at the wide-angle extremity, each 20 rotational sliding projection 18b is positioned in the associated rotational sliding groove 22d with the front sliding surface 18b-C and the rear sliding surface 18b-D of the rotational sliding projection 18b facing the front guide surface 22d-A and the rear guide surface 22d-B in 25 the associated rotational sliding groove 22d, so that the

helicoid ring 18 is prevented from moving in the optical axis direction relative to the stationary barrel 22.

When the set of three rotational sliding projections 18b move into the set of three rotational sliding grooves 22d, respectively, as shown in Figure 33, the set of three engaging projections 15b of the third external barrel 15 move into the set of three rotational sliding grooves 22d at the same time, respectively, so that the set of three engaging projections 15b are respectively pressed 10 against the front guide surfaces 22d-A in the set of three rotational sliding grooves 22d by the spring force of the three compression coil springs 25 and so that the set of three rotational sliding projections 18b of the helicoid ring 18 are respectively pressed against the rear guide 15 surfaces 22d-B in the set of three rotational sliding grooves 22d by the spring force of the three compression coil springs 25. The space between the front guide surfaces 22d-A and the rear guide surfaces 22d-B in the optical axis direction is determined to make the set of 20 three rotational sliding projections 18b and the set of three engaging projections 15b positioned closer to each other in the optical axis direction than those when the set of three rotational sliding projections 18b and the set of three engaging projections 15b are respectively 25 positioned in the set of three inclined grooves 22c. At

this time when the set of three rotational sliding projections 18b and the set of three engaging projections 15b are made to be positioned closer to each other in the optical axis direction, the three compression coil springs 25 are largely compressed to thereby apply a stronger spring force to the set of three engaging projections 15b and the set of three rotational sliding projections 18b than the spring force which is applied thereto by the three compression coil springs 25 when the zoom lens 71 is in the retracted state. Thereafter, while the set of three rotational sliding projections 18b and the set of three engaging projections 15b are positioned in the set of three rotational sliding grooves 22d, the set of three engaging projections 15b and the set of three rotational sliding projections 18b are pressed against each other by the spring force of the three compression coil springs 25. This stabilizes axial positions of the third external barrel 15 and the helicoid ring 18 relative to the stationary barrel 22 in the optical axis direction.

Namely, the third external barrel 15 and the helicoid ring 18 are supported by the stationary barrel 22 with no play between the third external barrel 15 and the helicoid ring 18 in the optical axis direction.

Rotating the third external barrel 15 and the helicoid ring 18 in the lens barrel advancing direction

from their respective wide-angle extremities (from the positions shown in Figures 24 and 28) causes the set of three engaging projections 15b and the set of three rotational sliding projections 18b (the rear sliding 5 surface 18b-D thereof) to firstly move toward the terminal ends of the set of three rotational sliding grooves 22d (upwards as viewed in Figure 28) while being guided by the front guide surfaces 22d-A and the rear guide surfaces 22d-B and subsequently reach telephoto extremities of the 10 third external barrel 15 and the helicoid ring 18 (the positions shown in Figures 25 and 29). Since the set of three engaging projections 15b and the set of three rotational sliding projections 18b remain engaged in the set of three rotational sliding grooves 22d, respectively, 15 the helicoid ring 18 and the third external barrel 15 are prevented from moving in the optical axis direction relative to the stationary barrel 22 and accordingly rotate about the lens barrel axis Z0 without moving in the optical axis direction relative to the stationary 20 barrel 22. In this state, the helicoid ring 18 is guided to be rotatable about the lens barrel axis Z0 mainly by the rear sliding surfaces 18b-D of the set of three rotational sliding projections 18b and the rear guide surfaces 22d-B of the stationary barrel 22 because the 25 helicoid ring 18 is biased rearward in the optical axis

direction by the three compression coil springs 25, i.e., in a direction to make the rear sliding surfaces 18b-D come into pressing contact with the rear guide surfaces 22d-B, respectively (see Figure 32).

5        When the helicoid ring 18 rotates at the axial fixed position, the cam ring 11 also rotates at the axial fixed position without moving in the optical axis direction relative to the first linear guide ring 14 because the set of three roller followers 32 are engaged in the front 10 circumferential slot portions 14e-1 of the set of three through-slots 14e, respectively. Accordingly, the first and second lens groups LG1 and LG2 move in the optical axis direction relative to each other in a predetermined moving manner to perform a zooming operation in accordance 15 with contours of respective zooming sections of the plurality of inner cam grooves 11a (11a-1 and 11a-2) and the set of three outer cam grooves 11b.

Further rotating the external barrel 15 and the helicoid ring 18 in the lens barrel advancing direction 20 to move the external barrel 15 and the helicoid ring 18 in the optical axis direction beyond their respective telephoto extremities causes the set of three rotational sliding projections 18b to reach the terminal ends (assembly/disassembly sections) of the set of three 25 rotational sliding grooves 22d as shown in Figures 26 and

30. In this state shown in Figures 26 and 30, movable elements of the zoom lens 71 such as the first through third external barrels 12, 13 and 15 can be removed from the stationary barrel 22 from the front thereof. However,  
5 if the stop member 26 is provided fixed to the stationary barrel 22 as shown in Figure 41, such movable elements cannot be removed from the stationary barrel 22 unless the stop member 26 is removed from the stationary barrel 22 because the engaging surface 18b-E, which is provided  
10 on specific one of the three rotational sliding projections 18b, comes into contact with the stop projection 26b of the stop member 26 to prevent the set of three rotational sliding projections 18b from reaching the terminal ends (assembly/disassembly sections) of the  
15 set of three rotational sliding grooves 22d,  
respectively..

Rotating the third external barrel 15 and the helicoid ring 18 in a lens barrel retracting direction (downwards as viewed in Figure 25) from their respective  
20 telephoto extremities causes the set of three rotational sliding projections 18b and the set of three engaging projections 15b to move toward the set of three inclined grooves 22c in the set of three rotational sliding grooves 22d, respectively. During this movement, the third  
25 external barrel 15 and the helicoid barrel 18 rotate

together about the lens barrel axis Z0 with no play between the third external barrel 15 and the helicoid ring 18 in the optical axis direction because the set of three engaging projections 15b are respectively pressed 5 against the front guide surfaces 22d-A in the set of three rotational sliding grooves 22d by the spring force of the three compression coil springs 25 while the set of three rotational sliding projections 18b of the helicoid ring 18 are respectively pressed against the rear guide 10 surfaces 22d-B in the set of three rotational sliding grooves 22d by the spring force of the three compression coil springs 25.

Further rotating the external barrel 15 and the helicoid ring 18 in the lens barrel retracting direction 15 beyond their respective wide-angle extremities (the positions shown in Figures 24 and 28) causes the circumferential end surfaces 18b-B of the set of three rotational sliding projections 18b to come into contact with the inclined surfaces 22c-B in the set of three 20 inclined grooves 22c, respectively. Thereupon, the movement of the helicoid ring 18 in the lens barrel retracting direction generates a component force in a direction to make the circumferential end surfaces 18b-B of the set of three rotational sliding projections 18b 25 move rearward in the optical axis direction along the

inclined surfaces 22c-B in the set of three inclined grooves 22c while sliding thereon, respectively, because the two circumferential end surfaces 18b-A and 18b-B of each of the three rotational sliding projections 18b are 5 parallel to the two opposed inclined surfaces 22c-A and 22c-B in the associated inclined groove 22c as shown in Figure 31, respectively. Therefore, the helicoid ring 18 starts moving rearward in the optical axis direction while rotating about the lens barrel axis Z0 in the reverse 10 manner to when the helicoid ring 18 moves forward while rotating. A slight rearward movement of the helicoid ring 18 in the optical axis direction by the engagement of the set of three rotational sliding projections 18b with the set of three inclined grooves 22c, respectively, 15 causes the male helicoid 18a to be engaged with the female helicoid 22a again. Thereafter, further rotating the helicoid ring 18 in the lens barrel retracting direction causes the helicoid barrel 18 to keep moving rearward in the optical axis direction by the engagement of the set 20 of three rotational sliding projections 18b with the set of three inclined grooves 22c, respectively, until the helicoid ring 18 reaches a retracted position thereof shown in Figures 23 and 27, i.e., until the zoom lens 71 is fully retracted. The third external barrel 15 moves 25 rearward in the optical axis direction while rotating

about the lens barrel axis Z0 due to the structures of the helicoid ring 18 and the first linear guide ring 14. During this rearward movement of the third external barrel 15, the set of three engaging projections 15b moves 5 together with the set of three rotational sliding projections 18b in the set of three inclined grooves 22c, respectively. When the helicoid ring 18 and the third external barrel 15 move rearward in the optical axis direction, the first linear guide ring 14 also moves 10 rearward in the optical axis direction, which causes the cam ring 11, which is supported by the first linear guide ring 14, to move rearward in the optical axis direction. In addition, at the time when the helicoid ring 18 starts moving rearward while rotating after rotating at the axial 15 fixed position, the set of three roller followers 32 are disengaged from the front circumferential slot portions 14e-1 to be engaged in the lead slot portions 14e-3, respectively, while the cam ring 11 moves rearward in the optical axis direction while rotating about the lens 20 barrel axis Z0 with respect to the first linear guide ring 14.

Upon the set of three rotational sliding projections 18b entering the set of three inclined grooves 22c from the set of three rotational sliding grooves 22d, 25 respectively, the third external barrel 15 and the

helicoid ring 18 change the relationship therebetween from the relationship in the ready-to-photograph state shown in Figures 33 and 34, in which the relative axial positions of the third external barrel 15 and the helicoid 5 ring 18 in the optical axis direction are finely determined, back to the relationship shown in Figures 35 and 36, in which the axial positions of the third external barrel 15 and the helicoid ring 18 are coarsely determined due to the engagement of the third external barrel 15 with 10 the first linear guide ring 14 with a clearance therebetween in the optical axis direction and the engagement of the helicoid barrel 18 with the first linear guide ring 14 with a clearance therebetween in the optical axis direction since either positions of the set of three 15 engaging projections 15b in the optical axis direction or positions of the set of three rotational sliding projections 18b in the optical axis direction are not limited by the set of three rotational sliding grooves 22d, respectively. In the state shown in Figures 35 and 20 36 in which the set of three rotational sliding projections 18b are engaged in the set of three inclined grooves 22c, the respective positions of the third external barrel 15 and the helicoid ring 18 in the optical axis direction do not need to be determined finely since 25 the zoom lens 71 is no longer in the ready-to-photograph

state.

As can be understood from the above descriptions, in the present embodiment of the zoom lens 71, a simple mechanism having the male and female helicoids 18a and 5 22a (that have male threads and female threads which are formed on radially-opposed outer and inner peripheral surfaces of the helicoid ring 18 and the stationary barrel 22, respectively), the set of three rotational sliding projections 18b, the set of three inclined grooves 22c 10 and the set of three rotational sliding grooves 22d can make the helicoid ring 18 perform a rotating-advancing/rotating-retracting operation in which the helicoid ring 18 rotates while moving forward or rearward in the optical axis direction, and a fixed-position 15 rotating operation in which the helicoid ring 18 rotates at a predetermined axial fixed position without moving in the optical axis direction relative to the stationary barrel 22. A simple fit between two ring members such as the helicoid ring 18 and the stationary barrel 22 with 20 a highly reliable precision in driving one of the two ring members relative to the other can generally be achieved with a fitting structure using helicoids (male and female helicoid threads). Moreover, the set of three rotational sliding projections 18b and the set of three rotational 25 sliding grooves 22d, which are adopted to make the

helicoid ring 18 rotatable at the axial fixed position which cannot be achieved by helicoids, also constitute a simple projection-depression structure similar to the above fitting structure using helicoids. Furthermore,  
5 the set of three rotational sliding projections 18b and the set of three rotational sliding grooves 22d are formed on the outer and inner peripheral surfaces of the helicoid ring 18 and the stationary barrel 22 on which the male helicoid 18a and the female helicoid 22a are also formed.  
10 This does not require any additional space for the installation of the set of three rotational sliding projections 18b and the set of three rotational sliding grooves 22d in the zoom lens 71. Accordingly, the aforementioned rotating-advancing/rotating-retracting  
15 operation and the fixed-position rotating operation that are performed by rotation of the helicoid ring 18 are achieved with a simple, compact and low-cost structure.

The zoom gear 28 has a sufficient length in the optical axis direction to remain engaged with the annular  
20 gear 18c of the helicoid ring 18 regardless of variations of the position thereof in the optical axis direction. Therefore, the zoom gear 28, that is provided as a single gear, can transfer rotation thereof to the helicoid ring 18 at all times in each of the rotating-advancing/rotating-retracting operation and the

fixed-position rotating operation of the helicoid ring 18. Accordingly, a simple and compact rotation transfer mechanism for transferring rotation to the helicoid ring 18 that presents intricate movements is achieved in the 5 present embodiment of the zoom lens, and the helicoid ring 18 and components associated therewith which are positioned inside the helicoid ring 18 can be driven with a high degree of precision.

As shown in Figures 31 and 32, the tooth depth of 10 each rotational sliding projection 18b of the female helicoid 18a is greater than that of each thread of the female helicoid 18a, and accordingly the set of three inclined grooves 22c and the set of three rotational sliding grooves 22d are formed to have greater tooth 15 depths than the threads of the female helicoid 22a. On the other hand, the zoom gear 28 is supported by the stationary barrel 22 so that the gear teeth formed around the zoom gear 28 project radially inwards from an inner peripheral surface of the stationary barrel 22 (from a 20 tooth flank of the female helicoid 22a) to be engaged with the annular gear 18c, which is formed on an outer peripheral surface of each thread of the male helicoid 18a. Therefore, the set of three rotational sliding projections 18b and gear teeth of the zoom gear 28 are 25 positioned in the same annular range (radial range) about

the lens barrel axis Z0 as viewed from the front of the zoom lens 71. However, the zoom gear 28 does not overlap the moving paths of set of three rotational sliding projections 18b because the zoom gear 28 is positioned 5 between two of the set of three inclined grooves 22c in a circumferential direction of the stationary barrel 22 and because the zoom gear 28 is installed on the stationary barrel 22 at a position different from the position of the set of three rotational sliding grooves 22d in the 10 optical axis direction. Accordingly, the set of three rotational sliding projections 18b do not interfere with the zoom gear 28 even though engaged in either the set of three inclined grooves 22c or the set of three rotational sliding grooves 22d.

15 It is possible that the set of three rotational sliding projections 18b and the zoom gear 28 be prevented from interfering with each other by reducing the amount of projection of the gear teeth of the zoom gear 28 from an inner peripheral surface of the stationary barrel 22 20 (from a tooth flank of the female helicoid 22a) so that the tooth depth of the zoom gear 28 becomes smaller than that of the male helicoid 18a. However, in this case, the amount of engagement of the teeth of the zoom gear 28 with the teeth of the male helicoid 18a will be small, 25 which makes it difficult to achieve a stable rotation of

the helicoid ring 18 when it rotates at the axial fixed position. Alternatively, if the tooth depth of the male helicoid 18a is increased without changing the amount of projection of each rotational sliding projection 18b,  
5 both the diameter of the stationary barrel 22 and the radial distance between the zoom gear 28 and the lens barrel axis Z0 increase accordingly. This increases the diameter of the zoom lens 71. Accordingly, if either the tooth depth of the male helicoid 18a or the amount of  
10 projection of the set of three rotational sliding projections 18b in radial directions of the helicoid ring 18 is changed to prevent the set of three rotational sliding projections 18b and the zoom gear 28 from interfering with each other, the helicoid ring 18 may not  
15 be driven with stability; moreover, a sufficient downsizing of the zoom barrel 71 may not be done. In contrast, according to the configurations of the zoom gear 28 and the set of three rotational sliding projections 18b shown in Figures 27 through 30, the set of three  
20 rotational sliding projections 18b and the zoom gear 28 can be prevented from interfering with each other without such problems.

In the present embodiment of the zoom lens 71, a rotatable portion of the zoom lens 71 which rotates at  
25 an axial fixed position at one time and also rotates while

moving forward or rearward in the optical axis direction at another time is divided into two parts: the third external barrel 15, and the helicoid ring 18 that are slightly movable relative to each other in the optical axis direction. In addition, the third external barrel 15 and the helicoid ring 18 are biased in opposite directions away from each other in the optical axis direction by the resilience of the three compression coil springs 25 to press the set of three engaging projections 15b of the third external barrel 15 against the front guide surfaces 22d-A in the set of three rotational sliding grooves 22d, respectively, and to press the set of three rotational sliding projections 18b of the helicoid ring 18 against the rear guide surfaces 22d-B in the set of three rotational sliding grooves 22d, respectively, to eliminate backlash between the third external barrel 15 and the stationary barrel 22 and backlash between the helicoid ring 18 and the stationary barrel 22. As described above, the set of three rotational sliding grooves 22d and the set of three rotational sliding projections 18b are elements of a drive mechanism for rotating the helicoid ring 18 at the axial fixed position or rotating the helicoid ring 18 while moving the same in the optical axis direction, and are also used as elements for removing the aforementioned backlashes.

This reduces the number of elements of the zoom lens 71.

The zoom lens 71 does not have to secure an additional space in the vicinity of the stationary barrel 22 in which the three compression coil springs 25 adopted 5 for removing backlash are accommodated because the three compression coil springs 25 are compressed and held between opposed end surfaces of the third external barrel 15 and the helicoid ring 18 that rotate in one piece about the lens barrel axis Z0. In addition, the set of three 10 engaging projections 15b are respectively received in the set of three engaging recesses 18e. This achieves a space-saving connected portion between the third external barrel 15 and the helicoid ring 18.

As described above, the three compression coil 15 springs 25 are largely compressed to apply a strong spring force to the set of three engaging projections 15b and the set of three rotational sliding projections 18b only when the zoom lens 71 is in the ready-to-photograph state.

Namely, the three compression coil springs 25 are not 20 largely compressed to apply a strong spring force to the set of three engaging projections 15b and the set of three rotational sliding projections 18b when the zoom lens 71 is not in the ready-to-photograph state, e.g., the retracted state. This reduces load on the associated 25 moving parts of the zoom lens 71 during the translation

of the zoom lens 71 from the retracted state to the ready-to-photograph state, especially at the beginning of driving the zoom lens in the lens barrel advancing operation, and also increases durability of the three  
5 compression coil springs 25.

The helicoid ring 18 and the third external barrel 15 are disengaged from each other firstly in the disassembling operation of the zoom lens 71. A zoom lens assembling mechanism which makes it easy for the zoom lens 10 71 to be assembled and disassembled, mainly elements of the zoom lens assembling mechanism which are associated with the helicoid ring 18 and the third external barrel 15, will be discussed hereinafter.

As described above, the stationary barrel 22 is 15 provided with the stop-member insertion hole 22e that radially penetrates the stationary barrel 22, from an outer peripheral surface of the stationary barrel 22 to a bottom surface of specific one of the three rotational sliding grooves 22d. The stationary barrel 22 is 20 provided on a surface thereof in the vicinity of the stop-member insertion hole 22e with a screw hole 22f and a stop member positioning protrusion 22g. The stop member 26, which is fixed to the stationary barrel 22 as shown in Figure 41, is provided with an arm portion 26a 25 which extends along an outer peripheral surface of the

stationary barrel 22, and the aforementioned stop projection 26b which projects radially inwards from the arm portion 26a. The stop member 26 is provided at one end thereof with an insertion hole 26c into which the set 5 screw 67 is inserted, and is further provided at the other end thereof with a hook portion 26d. The stop member 26 is fixed to the stationary barrel 22 by screwing the set screw 67 into the screw hole 22f through the insertion hole 26c with the hook portion 26d being engaged with the 10 stop member positioning protrusion 22g as shown in Figure 41. In a state where the stop member 26 is fixed to the stationary barrel 22 in this manner, the stop projection 26b is positioned in the stop-member insertion hole 22e so that the tip of the stop projection 26b projects inside 15 a specific rotational sliding groove 22d among the set of three rotational sliding grooves 22d. This state is shown in Figure 37. Note that the stationary barrel 22 is not shown in Figure 37.

The stationary barrel 22 is provided, at the front 20 end thereof on the front walls of the three rotational sliding grooves 22d, with three insertion/removable holes 22h through which the front of the stationary barrel 22 communicate with the three rotational sliding grooves 22d in the optical axis direction, respectively. Each 25 of the three insertion/removable holes 22h has a

sufficient width allowing the associated one of the three engaging projections 15b to be inserted into the insertion/removable hole 22h in the optical axis direction. Figure 42 shows one of the three 5 insertion/removable holes 22h and peripheral parts when the zoom lens 71 is set at the telephoto extremity as shown in Figures 25 and 29. As can be clearly seen in Figure 42, in the case where the zoom lens 71 is set at the telephoto extremity, the set of three engaging 10 projections 15b cannot be removed, toward the front of the zoom lens 71, from the three rotational sliding grooves 22d through the three insertion/removable holes 22h because the three engaging projections 15b and the three insertion/removable holes 22h are not aligned in 15 the optical axis direction (horizontal direction as viewed in Figure 42), respectively. This positional relationship is true for the remaining two insertion/removable holes 22h though only one of the three insertion/removable holes 22h is shown in Figure 42. On 20 the other hand, when the zoom lens 71 is set at the wide-angle extremity as shown in Figures 24 and 28, the three engaging projections 15b are respectively positioned further from the three insertion/removable holes 22h than the three engaging projections 15b shown 25 in Figures 25 and 29 in which the zoom lens 71 is set at

the telephoto extremity. This means that the set of three engaging projections 15b cannot be removed from the three rotational sliding grooves 22d through the three insertion/removable holes 22h, respectively, when the 5 zoom lens 71 is in the ready-to-photograph state, i.e., when the zoom lens 71 is set at a focal length between the wide-angle extremity and the telephoto extremity.

In order to align the three engaging projections 15b and the three insertion/removable holes 22h in the optical 10 axis direction, respectively, from the state shown in Figure 42 in which the zoom lens 71 is set at the telephoto extremity, the third external barrel 15 needs to be further rotated together with the helicoid ring 18 counterclockwise as viewed from the front of the zoom lens 15 71 relative to the stationary barrel 22 (upwards as viewed in Figure 42) by a rotational angle (disassembling rotational angle ) Rt1 (see Figure 42). However, in a state where the stop projection 26b is inserted into the stop-member insertion hole 22e as shown in Figure 41, if 20 the third external barrel 15 is rotated together with the helicoid ring 18 counterclockwise as viewed from the front of the zoom lens 71 relative to the stationary barrel 22 by a rotational angle (allowable rotational angle) Rt2 (see Figure 42), which is smaller than the disassembling 25 rotational angle Rt1, from the state shown in Figure 42

in which the zoom lens 71 is set at the telephoto extremity,  
the engaging surface 18b-E that is formed on one of the  
three rotational sliding projections 18b comes into  
contact with the stop projection 26b of the stop member  
5 26 to prevent the third external barrel 15 and the helicoid  
ring 18 from further rotating (see Figure 37). Since the  
allowable rotational angle  $Rt_2$  is smaller than the  
disassembling rotational angle  $Rt_1$ , the three engaging  
projections 15b and the three insertion/removable holes  
10 22h cannot be aligned in the optical axis direction,  
respectively, which makes it impossible to remove the set  
of three engaging projections 15b from the three  
rotational sliding grooves 22d through the three  
insertion/removable holes 22h, respectively. Namely,  
15 although terminal end portions of the set of three  
rotational sliding grooves 22d, which respectively  
communicate with the front of the stationary barrel 22  
through the three insertion/removable holes 22h, serve  
as assembly/disassembly sections, the third external  
20 barrel 15 cannot be rotated together with the helicoid  
ring 18 to a point where the set of three engaging  
projections 15b are positioned in the terminal end  
portions of the set of three rotational sliding grooves  
22d, respectively, as long as the stop member 26 remains  
25 fixed to the stationary barrel 22 with the stop projection

26b in the stop-member insertion hole 22e.

In the disassembling operation of the zoom lens 71, the stop member 26 needs to be removed from the stationary barrel 22 in the first place. If the stop member 26 is 5 removed, the stop projection 26b comes out of the stop-member insertion hole 22e. Once the stop projection 26b comes out of the stop-member insertion hole 22e, the third external barrel 15 and the helicoid ring 18 can be rotated together by the disassembling rotational angle 10  $Rt1$ . Rotating the third external barrel 15 and the helicoid ring 18 together by the disassembling rotational angle  $Rt1$  in a state where the zoom lens 71 is set at the telephoto extremity causes the third external barrel 15 and the helicoid ring 18 to be positioned to their 15 respective specific rotational positions relative to the stationary barrel 22 (hereinafter referred to as assembling/disassembling angular positions) as shown in Figures 26, 63. Figures 26 and 30 show a state of the zoom lens 71 where the third external barrel 15 and the 20 helicoid ring 18 have been rotated together by the disassembling rotational angle  $Rt1$  to be positioned in the respective assembling/disassembling angular positions from a state where the zoom lens 71 is set at the telephoto extremity. This state of the zoom lens 71, 25 in which the third external barrel 15 and the helicoid

ring 18 are positioned in the respective assembling/disassembling angular positions, is hereinafter referred to as an assemblable/disassemblable state. Figure 43 shows a portion of the stationary barrel 22 on which one of the three insertion/removable holes 22h is formed and portions of peripheral elements in the able-to-be assembled/disassembled state. As can be clearly understood from Figure 43, if the third external barrel 15 and the helicoid ring 18 have rotated by the 10 disassembling rotational angle Rt1 as shown in Figure 43, the three insertion/removable holes 22h and the three engaging recesses 18e that are formed on the set of three rotational sliding projections 18b are aligned in the optical axis direction so that the set of three engaging 15 projections 15b accommodated in the set of three engaging recesses 18e can be removed therefrom through the three insertion/removable holes 22h from the front of the zoom lens 71, respectively. Namely, the third external barrel 15 can be removed from the stationary barrel 22 from the 20 front thereof. Removing the set of three engaging projections 15b from the set of three engaging recesses 18e, respectively, causes the set of three engaging projections 15b of the third external barrel 15 and the set of three rotational sliding projections 18b of the 25 helicoid ring 18 to be free from the spring force of the

three compression coil springs 25, which are adopted to bias the set of three engaging projections 15b and the set of three rotational sliding projections 18b in opposite directions away from each other in the optical axis direction. At the same time, a function of the three rotational sliding projections 18b for removing backlash between the third external barrel 15 and the stationary barrel 22 and backlash between the helicoid ring 18 and the stationary barrel 22 is cancelled. The three engaging projections 15b and the three insertion/removable holes 22h are aligned in the optical axis direction when the set of three engaging projections 15b are in contact with the terminal ends (upward ends as viewed in Figure 28) of the set of three rotational sliding grooves 22d, respectively. Accordingly, the three engaging projections 15b and the three insertion/removable holes 22h are automatically aligned in the optical axis direction if the third external barrel 15 and the helicoid ring 18 are fully rotated together counterclockwise as viewed from the front of the zoom lens 71 relative to the stationary barrel 22, i.e., if the third external barrel 15 and the helicoid ring 18 are rotated together to the respective assembling/disassembling angular positions.

25            Although the third external barrel 15 can be removed

from the stationary barrel 22 when rotated to the assembling/disassembling angular position as shown in Figures 26 and 30, the third external barrel 15 is still engaged with the first linear guide ring 14 by the engagement of the plurality of relative rotation guide projections 15d with the circumferential groove 14d and the engagement of the second plurality of relative rotation guide projections 14c with the circumferential groove 15e. As can be seen in Figures 14 and 15, the second plurality of relative rotation guide projections 14c are formed on the first linear guide ring 14 at irregular intervals in a circumferential direction thereof, and some of the second plurality of relative rotation guide projections 14c have different circumferential widths than another ones. Likewise, the plurality of relative rotation guide projections 15d are formed on the third external barrel 15 at irregular intervals in a circumferential direction thereof, and some of the relative rotation guide projections 15d have different circumferential widths than another ones. The third external barrel 15 is provided at a rear end thereof with a plurality of insertion/removable holes 15g through which the second plurality of relative rotation guide projections 14c can be removed from the circumferential groove 15e in the optical axis direction, respectively,

only when the first linear guide ring 14 is positioned in a specific rotational position relative to the third external barrel 15. Likewise, the first linear guide ring 14 is provided at the front end thereof with a 5 plurality of insertion/removable holes 14h through which the plurality of relative rotation guide projections 15d can be removed from the circumferential groove 14d in the optical axis direction, respectively, only when the third external barrel 15 is positioned in a specific rotational 10 position relative to the first linear guide ring 14.

Figures 44 through 47 are developed views of the third external barrel 15 and the first linear guide ring 14, showing the relationship of coupling therebetween in different states. Specifically, Figure 44 shows a state 15 of coupling between the third external barrel 15 and the first linear guide ring 14 when the zoom lens 71 is in the retracted state (which corresponds to the state shown in each of Figures 23 and 27), Figure 45 shows the same when the zoom lens 71 is set at the wide-angle extremity 20 (which corresponds to the state shown in each of Figures 24 and 28), Figure 46 shows the same when the zoom lens 71 is set at the telephoto extremity (which corresponds to the state shown in each of Figures 25 and 29), and Figure 47 shows the same when the zoom lens 71 is in the 25 assemblable/disassemblable state (which corresponds to

the state shown in each of Figures 26 and 30). As can be seen from Figures 44 through 47, all of the second plurality of relative rotation guide projections 14c and the plurality of relative rotation guide projections 15d

5 cannot be inserted into or removed from the circumferential groove 15e and the circumferential groove 14d in the optical axis direction through the plurality of insertion/removable holes 15g and the plurality of insertion/removable holes 14h at the same

10 time, respectively, when the zoom lens 71 is in between the wide-angle extremity and the telephoto extremity, or even in between the wide-angle extremity and the retracted position, because some of the second plurality of relative rotation guide projections 14c and some of the plurality

15 of relative rotation guide projections 15d are engaged in the circumferential groove 15e and the circumferential groove 14d, respectively. Only when the third external barrel 15 and the helicoid ring 18 are rotated together to the respective assembling/disassembling angular

20 positions as shown in Figures 26 and 63 with the stop member having been removed, the second plurality of relative rotation guide projections 14c reach respective specific positions in the circumferential groove 15e at which the second plurality of relative rotation guide

25 projections 14c and the plurality of insertion/removable

holes 15g are aligned in the optical axis direction and at the same time the plurality of relative rotation guide projections 15d reach respective specific positions in the circumferential groove 14d at which the plurality of 5 relative rotation guide projections 15d and the plurality of insertion/removable holes 14h are aligned in the optical axis direction. This makes it possible to remove the third external barrel 15 from the first linear guide ring 14 from the front thereof as shown in Figures 47 and 10 56. Note that the stationary barrel 22 is not shown in Figure 56. If the third external barrel 15 is removed, the three compression coil springs 25, which are to be held between the third external barrel 15 and the helicoid ring 18, are exposed to the outside of the zoom lens 71, 15 and can be removed accordingly (see Figures 39 and 56).

Therefore, if the third external barrel 15 and the helicoid ring 18 are rotated together to the respective assembling/disassembling angular positions as shown in Figures 26 and 63 after the stop member has been removed, 20 the third external barrel 15 can be removed from both the stationary barrel 22 and the first linear guide ring 14 at the same time. In other words, the stop member 26 serves as a rotation limiting device for limiting the range of rotation of each of the third external barrel 25 15 and the helicoid ring 18 about the lens barrel axis

z0 relative to the stationary barrel 22 therein so that the third external barrel 15 and the helicoid ring 18 cannot be rotated together to the respective assembling/disassembling angular positions in a normal 5 operating state of the zoom lens 71. As can be understood from the above descriptions, a guiding structure consisting of the set of three rotational sliding projections 18b, the set of three rotational sliding grooves 22d and the set of three inclined grooves 22c is 10 simple and compact; moreover, if only the stop member 26 is added to the guiding structure, the range of rotation of each of the third external barrel 15 and the helicoid ring 18 about the lens barrel axis z0 relative to the stationary barrel 22 can be securely limited so that the 15 third external barrel 15 and the helicoid ring 18 cannot be rotated together to the respective assembling/disassembling angular positions in a normal operating state of the zoom lens 71.

Removing the third external barrel 15 from the zoom 20 lens 71 makes it possible to further disassemble the zoom lens 71 in a manner which will be discussed hereinafter. As shown in Figures 9 and 10, the third external barrel 15 is provided at the front end thereof with a frontmost inner flange 15h which projects radially inwards to close 25 the front ends of the set of six second linear guide

grooves 14g. The second external barrel 13, the set of six radial projections 13a of which are respectively engaged in the set of six second linear guide grooves 14g, cannot be removed from the front of the zoom lens 71 in

5 a state where the third external barrel 15 and the first linear guide ring 14 are coupled to each other because the frontmost inner flange 15h prevents the set of six radial projections 13a from being removed from the set of six second linear guide grooves 14g, respectively.

10 Hence, the second external barrel 13 can be removed from the first linear guide ring 14 once the third external barrel 15 is removed. However, the second external barrel 13 cannot be removed from the cam ring 11 in the optical axis direction if the discontinuous inner flange

15 13c remains engaged in the discontinuous circumferential groove 11c of the cam ring 11. As shown in Figure 20, the discontinuous inner flange 13c is formed as a discontinuous groove which is disconnected at irregular intervals in a circumferential direction of the second external barrel 13. On the other hand, as shown in Figure

20 16, the cam ring 11 is provided on outer peripheral surface thereof with a set of three external protuberances 11g which project radially outwards, while the discontinuous circumferential groove 11c is formed discontinuously on

25 only respective outer surfaces of the set of three

external protuberances 11g. The discontinuous circumferential groove 11c is provided on each of the three external protuberances 11g with an insertion/removable hole 11r which is open at the front 5 end of the external protuberance 11g. The insertion/removable holes 11r are arranged at irregular intervals in a circumferential direction of the cam ring 11.

Figures 52 through 55 are developed views of the 10 cam ring 11, the first external barrel 12 and the second external barrel 13, showing the relationship of coupling of each of the first external barrel 12 and the external barrel 13 to the cam ring 11 in different states. Specifically, Figure 52 shows a state of coupling of the 15 first external barrel 12 and the external barrel 13 to the cam ring 11 when the zoom lens 71 is in the retracted state (which corresponds to the state shown in each of Figures 23 and 27), Figure 53 shows the same when the zoom lens 71 is set at the wide-angle extremity (which 20 corresponds to the state shown in each of Figures 24 and 28), Figure 54 shows the same when the zoom lens 71 is set at the telephoto extremity (which corresponds to the state shown in each of Figures 25 and 29), and Figure 55 shows the same when the zoom lens 71 is in the 25 assemblable/disassemblable state (which corresponds to

the state shown in each of Figures 26 and 30). As can be seen from Figures 52 through 54, the second external barrel 13 cannot be removed from the cam ring 11 in the optical axis direction when the zoom lens 71 is in between 5 the wide-angle extremity and the telephoto extremity, or even in between the wide-angle extremity and the retracted position because some portions of the discontinuous inner flange 13c are engaged in at least a part of the discontinuous circumferential groove 11c. Only when the 10 third external barrel 15 and the helicoid ring 18 are rotated together to the respective assembling/disassembling angular positions as shown in Figures 26 and 63, the rotation of the third external barrel 15 causes the cam ring 11 to rotate to a specific 15 rotational position thereof at which all the portions of the discontinuous inner flange 13c of the second external barrel 13 are exactly aligned with the three insertion/removable hole 11r or the three circumferential spaces among the three external 20 protuberances 11g, respectively. This makes it possible to remove the second external barrel 13 from the cam ring 11 from the front thereof as shown in Figures 55 and 57.

In addition, in the state shown in Figure 55 in which the zoom lens 71 is in the assemblable/disassemblable 25 state, the set of three cam followers 31 on the first

external barrel 12 are positioned close to the front open ends of the set of three outer cam grooves 11b, respectively, so that the first external barrel 12 can be removed from the front of the zoom lens 71 as shown 5 in Figure 58. In addition, the first lens group adjustment ring 2 can also be removed from the second external barrel 12 after the two set screws 64 are screwed off to remove the fixing ring 3 as shown in Figure 2. Thereafter, the first lens frame 1 that is supported by 10 the first lens group adjustment ring 2 therein can also be removed from the first lens group adjustment ring 2 from the front thereof.

Although the first linear guide ring 14, the helicoid ring 18, the cam ring 11, and some other elements 15 in the cam ring 11 such as the second lens group moving frame 8 still remain in the stationary barrel 22 in the state shown in Figure 58, the zoom lens 71 can be further disassembled as needed.

As can be seen from Figures 57 and 58, if the third 20 external barrel 15 is removed with the zoom lens 71 being fully extended forward from the stationary barrel 22, each of the three set screws 32a becomes accessible. Thereafter, if the set of three roller followers 32 are removed together with the three set screws 32a as shown 25 in Figure 59, a combination of the cam ring 11 and the

second linear guide ring 10 can be removed from the first linear guide ring 14 from the rear thereof because no elements of the zoom lens 71 prevent the cam ring 11 from moving rearward in the optical axis direction relative 5 to the first linear guide ring 14. As shown in Figures 15 and 59, front ends of each pair of first linear guide grooves 14f, in which the pair of radial projections of the associated bifurcated projection 10a are engaged, are each formed as a closed end while rear ends of the same 10 are each formed as an open end at the rear end of the first linear guide ring 14. Accordingly, the combination of the cam ring 11 and the second linear guide ring 10 can be removed from the first linear guide ring 14 only from the rear thereof. Although the second linear guide ring 15 and the cam ring 11 are coupled to each other with the discontinuous outer edge of the ring portion 10b being engaged in the discontinuous circumferential groove 11e to be rotatable relative to each other about the lens barrel axis Z0, the second linear guide ring 10 and the 20 cam ring 11 can be disengaged from each other as shown in Figure 3 when one of the second linear guide ring 10 and the cam ring 11 is positioned in a specific rotational position relative to the other.

When the third external barrel 15 and the helicoid 25 ring 18 are rotated together to the respective

assembling/disassembling angular positions as shown in Figures 26 and 63, the set of three front cam followers 8b-1 are removed from the set of three front inner cam grooves 11a-1 in the optical axis direction from the front 5 of the cam ring 11 while the set of three rear cam followers 8b-2 are positioned in front open end sections 11a-2x of the set of three rear inner cam grooves 11a-2, respectively. Therefore, the second lens group moving frame 8 can be removed from the cam ring 11 from the front 10 thereof as shown in Figure 3. Since the front open end sections 11a-2x of the set of three rear inner cam grooves 11a-2 are formed as linear grooves extending in the optical axis direction, the second lens group moving frame 8 can be removed from the cam ring 11 from the front thereof 15 regardless of whether the second lens group moving frame 8 is guided linearly in the optical axis direction by the second linear guide ring 10, i.e., whether or not the set of three front cam followers 8b-1 and the set of three rear cam followers 8b-2 are engaged in the set of three 20 front inner cam grooves 11a-1 and the set of three rear inner cam grooves 11a-2, respectively. In the state shown in Figure 58 in which the cam ring 11 and the second linear guide ring 10 remain inside the first linear guide ring 14, only the second lens group moving frame 8 can 25 be removed.

The pivot shaft 33 and the second lens frame 6 can be removed from the second lens group moving frame 8 after the set screws 66 are unscrewed to remove the pair of second lens frame support plates 36 and 37 (see Figure 5 3).

Aside from the elements positioned inside the cam ring 11, the helicoid ring 18 can be removed from the stationary barrel 22. In this case, after the CCD holder 10 is removed from the stationary barrel 22, the helicoid ring 18 is rotated in the lens barrel retracting direction from the assembling/disassembling angular position to be removed from the stationary barrel 22. This rotation of the helicoid ring 18 in the lens barrel retracting direction causes the set of three rotational sliding 15 projections 18b to move back into the set of three inclined grooves 22c from the set of three rotational sliding grooves 22d so that the male helicoid 18a is engaged with the female helicoid 22a, thus causing the helicoid ring 18 to move rearward while rotating about the lens barrel 20 axis Z0. Upon the helicoid ring 18 moving rearward beyond the position thereof shown in Figures 23 and 27, the set of three rotational sliding projections 18b are respectively removed from the set of three inclined grooves 22c from rear open end sections 22c-x thereof 25 while the male helicoid 18a is disengaged from the female

helicoid 22a. Consequently, the helicoid ring 18, together with the linear guide ring 14, is removed from the stationary barrel 22 from the rear thereof.

The helicoid ring 18 and the linear guide ring 14  
5 are engaged with each other by engagement of the first plurality of relative rotation guide projections 14b with the circumferential groove 18g. Similar to the second plurality of relative rotation guide projections 14c, the first plurality of relative rotation guide projections  
10 14b are formed on the first linear guide ring 14 at irregular intervals in a circumferential direction thereof, and some of the first plurality of relative rotation guide projections 14b have different circumferential widths than another ones. The helicoid  
15 ring 18 is provided on an inner peripheral surface thereof with a plurality of insertion/removable grooves 18h via which the first plurality of relative rotation guide projections 14b can enter the helicoid ring 18 (the circumferential groove 18g) in the optical axis direction,  
20 respectively, only when the first linear guide ring 14 is positioned in a specific rotational position relative to the helicoid ring 18.

Figures 48 through 51 show developed views of the first linear guide ring 14 and the helicoid ring 18,  
25 showing the relationship of coupling therebetween in

different states. Specifically, Figure 48 shows a state of coupling between the first linear guide ring 14 and the helicoid ring 18 when the zoom lens 71 is in the retracted state (which corresponds to the state shown in 5 each of Figures 23 and 27), Figure 49 shows another state of coupling between the first linear guide ring 14 and the helicoid ring 18 when the zoom lens 71 is set at the wide-angle extremity (which corresponds to the state shown in each of Figures 24 and 28), Figure 50 shows the 10 same when the zoom lens 71 is set at the telephoto extremity as shown in Figures 25 and 29, and Figure 51 shows another state of coupling between the first linear guide ring 14 and the helicoid ring 18 when the zoom lens 71 is in the assemblable/disassemblable state (which 15 corresponds to the state shown in each of Figures 26 and 30). As can be seen from Figures 48 through 51, when the zoom lens 71 is in between the retracted position and the position in the assemblable/disassemblable state, in which the third external barrel 15 and the helicoid ring 20 18 are positioned in the respective assembling/disassembling angular positions as shown in Figures 26 and 63, all of the first plurality of relative rotation guide projections 14b cannot be inserted into or removed from the plurality of insertion/removable 25 grooves 18h at the same time, respectively, which makes

it impossible to disengage the helicoid ring 18 and the first linear guide ring 14 from each other in the optical axis direction. All the first plurality of relative rotation guide projections 14b can be inserted into or 5 removed from the plurality of insertion/removable grooves 18h at the same time, respectively, only when the helicoid ring 18 is further rotated in the lens barrel retracting direction (downwards as viewed in Figure 48) to a specific rotational position beyond the retracted 10 position of the helicoid ring 18 shown in Figure 48. After the helicoid ring 18 has been rotated to the specific rotational position, moving the helicoid 18 forward (leftward as viewed in Figures 48 through 51) with respect 15 to the first linear guide ring 14 causes the first plurality of relative rotation guide projections 14b to be removed from the plurality of insertion/removable grooves 18h to the rear of the circumferential groove 18g, respectively. Alternatively, it is possible to modify the structure coupling between the first linear guide ring 20 14 and the helicoid ring 18 so that all the first plurality of relative rotation guide projections 14b can pass the helicoid ring 18 in the optical axis direction through the plurality of insertion/removable grooves 18h at the same time when the helicoid ring 18 and the linear guide 25 ring 14 are positioned at the aforementioned respective

rotational positions at which the helicoid ring 18 and the linear guide ring 14 can be removed from the stationary barrel 22.

The second plurality of relative rotation guide projections 14c, which are engaged in the circumferential groove 15e of the third external barrel 15, are formed in front of the first plurality of relative rotation guide projections 14b on first linear guide ring 14 in the optical axis direction. As described above, the first plurality of relative rotation guide projections 14b are formed as circumferentially elongated projections at different circumferential positions on the first linear guide ring 14 while the second plurality of relative rotation guide projections 14c are formed as circumferentially elongated projections at different circumferential positions on the first linear guide ring 14. More specifically, although the respective positions of the first plurality of relative rotation guide projections 14b are not coincident with those of the second plurality of relative rotation guide projections 14c in a circumferential direction of the first linear guide ring 14, the first plurality of relative rotation guide projections 14b and the second plurality of relative rotation guide projections 14c are the same as each other in the number of projections,

intervals of projections, and circumferential widths of corresponding projections as shown in Figure 15. Namely, there is a specific relative rotational position between the second plurality of relative rotation guide 5 projections 14c and the plurality of insertion/removable grooves 18h, in which the second plurality of relative rotation guide projections 14c and the plurality of insertion/removable grooves 18h can be disengaged from each other in the optical axis direction. If the helicoid 10 ring 18 is moved forward from the first linear guide ring 14 in a state where the second plurality of relative rotation guide projections 14c and the plurality of insertion/removable grooves 18h are in such a specific relative rotational position, each relative rotation 15 guide projections 14c can be inserted into the corresponding insertion/removable groove 18h from the front end thereof and subsequently removed from the same insertion/removable groove 18h from the rear end thereof so that the helicoid ring 18 can be removed from the first 20 linear guide ring 14 from the front thereof. Accordingly, the front and rear ends of each insertion/removable groove 18h are respectively formed as open ends so that the associated relative rotation guide projections 14c can pass the helicoid ring 18 in the optical axis direction 25 through the insertion/removable groove 18h.

Namely, the helicoid ring 18 and the first linear guide ring 14 are not in a disengagable state until the helicoid ring 18 and the first linear guide ring 14 are removed from the stationary barrel 22 and relatively 5 rotated by a predetermined amount of rotation. In other words, when disassembling the third external barrel 15, the helicoid ring 18 and the first linear guide ring 14 are mutually engaged with each other while being supported inside the stationary barrel 22. The assembly process 10 is accordingly facilitated by disallowing the first linear guide ring 14 from being disengaged.

As can be understood from the foregoing, in the present embodiment of the zoom lens, the third external barrel 15, which performs the rotating-advancing/rotating-retracting operation and the fixed-position rotating operation, can be easily removed 15 from the zoom lens 71 by rotating the third external barrel 15 and the helicoid ring 18 together to the respective assembling/disassembling angular positions as shown in Figures 26 and 63, which are different from any of their 20 respective positions in either of the zooming range and the retracting range, after the stop member 26 has been removed from the stationary barrel 22. Moreover, a function of the three rotational sliding projections 18b 25 for removing backlash between the third external barrel

15 and the stationary barrel 22 and backlash between the helicoid ring 18 and the stationary barrel 22 can be cancelled by removing the third external barrel 15 from the zoom lens 71. Furthermore, when the zoom lens 71 is  
5 in the assemblable/disassemblable state, in which the third external barrel 15 can be inserted into or removed from the zoom lens 71, the second external barrel 13, the first external barrel 12, the cam ring 11, the second lens group moving frame 8 and other elements are also  
10 positioned at their respective assembling/disassembling positions to become removable from the zoom lens 71 one after another after the third external barrel 15 is removed from the zoom lens 71. This results in an improvement in workability of disassembling the zoom lens  
15 71.

Although only a disassembling procedure of the zoom lens 71 has been discussed above, a reverse procedure to the above disassembling procedure can be performed as an assembling procedure of the zoom lens 71. This also  
20 results in an improvement in workability of assembling the zoom lens 71.

Another feature of the zoom lens 71 which is associated with the third external barrel 15 (and also the helicoid ring 18) will be hereinafter discussed with  
25 reference mainly to Figures 60 through 72. In Figures

60 through 63, some portions of the linear guide ring 14 and the third external barrel 15, and the follower-biasing ring spring 17 for biasing the set of three roller followers 32 would not normally be visible (i.e., are 5 supposed to be shown by hidden lines), but are shown by solid lines for the purpose of illustration. Figures 64 through 66 show portions of the third external barrel 15 and the helicoid ring 18, viewed from the inside thereof, and accordingly the direction of inclination of, e.g. the 10 inclined lead slot portion 14e-3 appeared in Figure 64 and 65, is opposite to that shown in the other Figures.

As can be understood from the above descriptions, in the present embodiment of the zoom lens 71, a rotatable barrel positioned immediately inside the stationary barrel 22 (namely, the first rotatable barrel when viewed from the side of the stationary barrel 22) is divided into two parts: the third external barrel 15 and the helicoid ring 18. In the following descriptions, the third external barrel 15 and the helicoid ring 18 are referred 15 to as a rotatable barrel KZ in some cases for clarity (e.g., see Figures 23 through 26, 60 through 62). The function of the rotatable barrel KZ is to impart motion to the set of three roller followers 32 to rotate the set of three roller followers 32 about the lens barrel axis Z0. The 20 cam ring 11 receives force, which makes the cam ring 11

rotate about the lens barrel axis Z0 while moving in the optical axis direction, via the set of three roller followers 32 to move the first and second lens groups LG1 and LG2 in the optical axis direction in a predetermined 5 moving manner. Engaging portions of the rotatable barrel KZ which are engaged with the set of three roller followers 32, i.e., the set of three rotation transfer grooves 15f satisfy some conditions which will be hereinafter discussed.

10 First of all, the set of three rotation transfer grooves 15f, in which the set of three roller followers 32 are engaged, need to have lengths corresponding to the range of movement of the set of three roller followers 32 in the optical axis direction. This is because each 15 roller follower 32 is not only rotated about the lens barrel axis Z0 between a retracted position shown in Figure 60 and a position shown in Figure 62 which corresponds to the telephoto extremity of the zoom lens 71 via a position shown in Figure 61 which corresponds 20 to the wide-angle extremity of the zoom lens 71, but also moved in the optical axis direction relative to the rotatable barrel KZ by the associated inclined lead slot portion 14e-3 of the first linear guide ring 14.

The third external barrel 15 and the helicoid ring 25 18 substantially operate as a one-piece rotatable barrel:

the rotatable barrel KZ. This is because the third external barrel 15 and the helicoid ring 18 are prevented from rotating relative to each other by engagement of the three pairs of rotation transfer projections 15a with the 5 three rotation transfer recesses 18d, respectively. However, in the present embodiment of the zoom lens, since the third external barrel 15 and the helicoid ring 18 are provided as separate members for the purpose of assembling and disassembling the zoom lens 71, there is provided a 10 slight clearance between each pair of rotation transfer projections 15a and the associated rotation transfer recess 18d in a rotational direction (vertical direction as viewed in Figure 66). More specifically, as shown in Figure 66, the three pairs of rotation transfer 15 projections 15a and the three rotation transfer recesses 18d are formed so that a circumferential space WD1 between circumferentially-opposed two side surfaces 18d-S of the helicoid ring 18 in each rotation transfer recess 18d that extend parallel to each other becomes slightly greater 20 than a circumferential space WD2 between opposite end surfaces 15a-S of the associated pair of rotation transfer projections 15a that also extend parallel to each other. Due to this clearance, the third external barrel 15 and the helicoid ring 18 slightly rotate relative to each 25 other about the lens barrel axis Z0 when one of the third

external barrel 15 and the helicoid ring 18 is rotated about the lens barrel axis Z0 relative to the other. For instance, in the state shown in Figure 64, if the helicoid ring 18 is rotated in the lens barrel advancing direction 5 shown by an arrow AR1 in Figure 65 (downwards as viewed in Figures 64 and 65) with respect to the third external barrel 15, the helicoid ring 18 rotates in the same direction by an amount of rotation "NR" with respect to the third external barrel 15 so that one of the 10 circumferentially-opposed two side surfaces 18d-S in each rotation transfer recess 18d comes into contact with corresponding one of the opposite end surfaces 15a-S of the associated pair of rotation transfer projections 15a as shown in Figure 65. Therefore, the set of three 15 rotation transfer grooves 15f must be formed on the third external barrel 15 to be capable of guiding the set of three roller followers 32 smoothly in the optical axis direction at all times regardless of the presence or absence of a variation in the relative rotational position 20 between the third external barrel 15 and the helicoid ring 18 that is caused by the presence of the clearance between each pair of rotation transfer projections 15a and the associated rotation transfer recess 18d. This clearance 25 is exaggerated in the drawings for the purpose of illustration.

In the present embodiment of the zoom lens, the three pairs of rotation transfer projections 15a that extend rearward in the optical axis direction are formed on the third external barrel 15 as engaging portions thereof for 5 engaging the third external barrel 15 with the helicoid ring 18. This structure of the three pairs of rotation transfer projections 15a has been fully utilized for the formation of the set of three rotation transfer grooves 15f on the third external barrel 15. More specifically, 10 the major portion of each rotation transfer groove 15f is formed on an inner peripheral surface of the third external barrel 15 so that the circumferential positions of the three rotation transfer grooves 15f correspond to those of the three pairs of rotation transfer projections 15a, respectively. In addition, the remaining rear end portion of each rotation transfer groove 15f is elongated rearward in the optical axis direction to be formed between opposed guide surfaces 15f-S (see Figure 66) of the associated pair of rotation transfer projections 15a.

20 No gaps or steps are formed in each rotation transfer groove 15f because each rotation transfer groove 15f is formed only on the third external barrel 15, not formed as a groove extending over the third external barrel 15 and the helicoid ring 18. Even if the relative rotational position between the third external barrel 15 and the

helicoid ring 18 slightly varies due to the clearance between each pair of rotation transfer projections 15a and the associated rotation transfer recess 18d, the opposed guide surfaces 15f-S of each rotation transfer 5 groove 15f remain invariant in shape. Therefore, the set of three rotation transfer grooves 15f are capable of guiding the set of three roller followers 32 smoothly in the optical axis direction at all times.

The set of three rotation transfer grooves 15f can 10 be formed to have sufficient lengths in the optical axis direction by making most of the three pairs of rotation transfer projections 15a that project in the optical axis direction, respectively. As shown in Figures 60 through 62, a range of movement D1 of the set of three roller 15 followers 32 in the optical axis direction (see Figure 60) is greater than an axial length D2 of an area on the inner peripheral surface of the third external barrel 15 (except for the three pairs of rotation transfer projections 15a) in the optical axis direction on which 20 grooves extending in the optical axis direction can be formed. Specifically, in the state shown in Figures 60 and 64 in which the zoom lens 71 is in the retracted state as shown in Figure 10, each roller follower 32 has moved rearward to a point (retracted point) between the front 25 and rear ends of the helicoid ring 18 in the optical axis

direction. However, since each pair of rotation transfer projections 15a extends rearward to a point corresponding to the retracted point between the front and rear ends of the helicoid ring 18 in the optical axis direction  
5 because the three pairs of rotation transfer projections 15a need to remain engaged in the three rotation transfer recesses 18d, respectively, the engagement of the set of three roller followers 32 with the set of three rotation transfer grooves 15f is maintained even if the set of three  
10 roller followers 32 are moved rearward to the respective retracted points. Accordingly, the set of three roller followers 32 can be guided in the optical axis direction in a range of movement extending over the third external barrel 15 and the helicoid ring 18 even if guiding portions  
15 (the set of three rotation transfer grooves 15f) which are engaged with the set of three roller followers 32 (to guide the set of three roller followers 32) are formed only on the third external barrel 15 of the rotatable barrel KZ.

20 Even though the circumferential groove 15e intersects each rotation transfer groove 15f on the inner peripheral surface of the third external barrel 15, the circumferential groove 15e does not deteriorate the guiding function of the set of three rotation transfer  
25 grooves 15f because the depth of the circumferential

groove 15e is smaller than that of each rotation transfer groove 15f.

Figures 67 and 68 show a comparative example which is to be compared with the above described structure shown mainly in Figures 64 through 66. In this comparative example, a front ring 15' (which corresponds to the third external barrel 15 of the present embodiment of the zoom lens) is provided with a set of three rotation transfer grooves 15f' (only one of them is shown in Figures 67 and 10 68) extending linearly in the optical axis direction, while a rear ring 18' (which corresponds to the helicoid ring 18 of the present embodiment of the zoom lens) is provided with a set of three extension grooves 18x extending linearly in the optical axis direction. A set 15 of three roller followers 32' (which corresponds to the set of three roller followers 32 of the present embodiment of the zoom lens 71) are engaged in the set of three rotation transfer grooves 15f' or the set of three extension grooves 18x so that each roller follower 32' 20 can move in the associated rotation transfer groove 15f' and the associated extension groove 18x in the optical axis direction. Namely, the set of three roller followers 32' are respectively movable in a set of three grooves extending over the front ring 15' and the rear 25 ring 18'. The front ring 15' and the rear ring 18' are

engaged with each other via a plurality of rotation transfer projections 15a' of the front ring 15' and a corresponding plurality of rotation transfer grooves 18d' of the rear ring 18' in which the plurality of 5 rotation transfer projections 15a' are respectively engaged. The plurality of rotation transfer projections 15a' are formed on a rear end surface of the front ring 15' which faces a front surface of the rear ring 18', while the plurality of rotation transfer grooves 18d' are formed 10 on the front surface of the rear ring 18'. There is a slight clearance between the plurality of rotation transfer projections 15a' and the plurality of rotation transfer grooves 18d' in a rotational direction (vertical direction as viewed in Figure 68). Figure 67 shows a 15 state where the set of three rotation transfer grooves 15f' and the set of three extension grooves 18x are precisely aligned in the optical axis direction.

In the comparative example having the above described structure, in the state shown in Figure 67, if 20 the front ring 18' is rotated in a direction shown by an arrow AR1' in Figure 68 (downwards as viewed in Figures 67 and 68) with respect to the rear ring 18', the rear ring 18' slightly rotates in the same direction due to the aforementioned clearance between the plurality of 25 rotation transfer projections 15a' and the plurality of

rotation transfer grooves 18d'. This causes a misalignment between the set of three rotation transfer grooves 15f' and the set of three extension grooves 18x. Therefore, in the state shown in Figure 68, a gap is 5 produced between a guide surface of each rotation transfer groove 15f' and a corresponding guide surface of the associated extension groove 18x. This gap may interfere with a movement of each roller follower 32' in the associated rotation transfer groove 15f' and the 10 associated extension groove 18x in the optical axis direction, which cannot ensure a smooth movement of each roller follower 32'. If the gap becomes large, each roller follower 32' may not be able to move between the associated rotation transfer groove 15f' and the 15 associated extension groove 18x across a border therebetween.

Supposing either the set of rotation transfer grooves 15f' or the set of extension grooves 18x is omitted to prevent such an undesirable gap from being produced 20 between a guide surface of each rotation transfer groove 15f' and a corresponding guide surface of the associated extension groove 18x, the other set of rotation transfer grooves 15f' or extension grooves 18x may need to be elongated in the optical axis direction. Consequently, 25 the length of either the front ring 15' or the rear ring

18' in the optical axis direction will increase. For instance, if it is desired to omit the set of extension grooves 18x, each rotation transfer groove 15f' must be elongated forward by a length corresponding to the length 5 of each extension groove 18x. This increases the dimensions of the zoom lens, specifically the length thereof.

In contrast to this comparative example, the present embodiment of the zoom lens, in which the three pairs of 10 rotation transfer projections 15a that extend rearward in the optical axis direction are formed on the third external barrel 15 as engaging portions thereof for engaging the third external barrel 15 with the helicoid ring 18, has the advantage that the set of three rotation 15 transfer grooves 15f are respectively capable of guiding the set of three roller followers 32 smoothly in the optical axis direction at all times without any gaps being produced in the set of three rotation transfer grooves 15f. Moreover, the present embodiment of the zoom lens 20 has the advantage that each rotation transfer groove 15f can be formed to have a sufficient effective length without the third external barrel 15 being elongated forward in the optical axis direction.

Exerting a force to the set of three roller followers 25 32 in a direction to rotate the same about the lens barrel

axis Z0 via the set of three rotation transfer grooves 15f causes the cam ring 11 to rotate about the lens barrel axis Z0 while rotating in the optical axis direction due to engagement of the set of three roller followers 32 with 5 the lead slot portions 14e-3 of the set of three through-slots 14e, respectively, when the zoom lens 71 is set in between the wide-angle extremity and the retracted position. When the zoom lens 71 is in the zooming range, the cam ring 11 rotates at the axial fixed 10 position without moving in the optical axis direction due to engagement of the set of three roller followers 32 with the front circumferential slot portions 14e-1 of the set of three through-slots 14e, respectively. Since the cam ring 11 rotates at the axial fixed position in the 15 ready-to-photograph state of the zoom lens 71, the cam ring 11 must be positioned precisely at a predetermined position in the optical axis direction to insure optical accuracy of movable lens groups of the zoom lens 71 such as the first lens group LG1 and the second lens group LG2. 20 Although the position of the cam ring 11 in the optical axis direction when the cam ring 11 rotates at the axial fixed position thereof is determined by the engagement of the set of three roller followers 32 with the front circumferential slot portions 14e-1 of the set of three 25 through-slots 14e, respectively, a clearance is provided

between the set of three roller followers 32 and the front circumferential slot portions 14e-1 so that the set of three roller followers 32 can smoothly move in the front circumferential slot portions 14e-1 of the set of three through-slots 14e, respectively. Accordingly, it is necessary to remove backlash between the set of three roller followers 32 and the set of three through-slots 14e which is caused by the clearance when the set of three roller followers 32 are engaged in the front circumferential slot portions 14e-1 of the set of three through-slots 14e, respectively.

The follower-biasing ring spring 17 for removing the backlash is positioned inside the third external barrel 15, and a structure supporting the follower-biasing ring spring 17 is shown in Figures 33, 35, 63 and 69 through 72. The frontmost inner flange 15h is formed on the third external barrel 15 to extend radially inwards from a front end of the inner peripheral surface of the third external barrel 15. As shown in Figure 63, the follower-biasing ring spring 17 is a non-flat annular member which is provided with a plurality of bends which are bent in the optical axis direction to be resiliently deformable in the optical axis direction. More specifically, the follower-biasing ring spring 17 is disposed so that the set of three follower pressing protrusions 17a are

positioned at the rear end of the follower-biasing ring spring 17 in the optical axis direction. The follower-biasing ring spring 17 is provided with a set of three forwardly-projecting arc portions 17b which 5 project forward in the optical axis direction. The three forwardly-projecting arc portions 17b and the three follower pressing protrusions 17a are alternately arranged to form the follower-biasing ring spring 17 as shown in Figures 4, 14 and 63. The follower-biasing ring 10 spring 17 is disposed between the frontmost inner flange 15h and the plurality of relative rotation guide projections 15d in a slightly compressed state so as not to come off the third external barrel 15 from the inside thereof. If the set of three forwardly-projecting arc 15 portions 17b are installed between the frontmost inner flange 15h and the plurality of relative rotation guide projections 15d with the set of three follower pressing protrusions 17a and the set of three rotation transfer grooves 15f being aligned in the optical axis direction, the set of three follower pressing protrusions 17a are 20 engaged in respective front portions of the set of three rotation transfer grooves 15f to be supported thereby. When the first linear guide ring 14 is not attached to the third external barrel 15, each follower pressing 25 protrusion 17a is sufficiently apart from the frontmost

inner flange 15h of the third external barrel 15 in the optical axis direction as clearly shown in Figure 72 to be movable to a certain degree in the associated rotation transfer groove 15f.

5        When the first linear guide ring 14 is attached to the third external barrel 15, the set of three forwardly-projecting arc portions 17b of the follower-biasing ring spring 17 are deformed by being pressed forward, toward the frontmost inner flange 15h, 10 by the front end of the linear guide ring 14 to make the shape of the set of three forwardly-projecting arc portions 17b become close to a flat shape. When the follower-biasing ring spring 17 is deformed in such a manner, the first linear guide ring 14 is biased rearward 15 by the resiliency of the follower-biasing ring spring 17 to thereby fix the position of the first linear guide ring 14 with respect to the third external barrel 15 in the optical axis direction. At this time, a front guide surface in the circumferential groove 14d of the first 20 linear guide ring 14 is pressed against respective front surfaces of the plurality of relative rotation guide projections 15d, while respective rear surfaces of the second plurality of relative rotation guide projections 14c are pressed against a rear guide surface in the circumferential groove 15e of the third external barrel 25

15 in the optical axis direction, as clearly shown in Figure 69. At the same time, the front end of the first linear guide ring 14 is positioned between the frontmost inner flange 15h and the plurality of relative rotation 5 guide projections 15d in the optical axis direction, while front surfaces the set of three forwardly-projecting arc portions 17b of the follower-biasing ring spring 17 are not entirely in pressing contact with the frontmost inner flange 15h. Therefore, when the zoom lens 71 is in the 10 retracted state, a slight space is secured between the set of three follower pressing protrusions 17a and the frontmost inner flange 15h so that each follower pressing protrusion 17a can move to a certain extent in the associated rotation transfer groove 15f in the optical 15 axis direction. In addition, as shown in Figures 35 and 69, each follower pressing protrusion 17a which extends rearward that the tip thereof (rear end thereof in the optical axis direction) is positioned inside the front circumferential slot portion 14e-1 of the associated 20 radial slot 14.

In the state shown in Figures 60 and 64 in which the zoom lens 71 is in the retracted state, the follower-biasing ring spring 17 do not contact with any elements other than the first linear guide ring 14. At this time, 25 although engaged in the set of three rotation transfer

grooves 15f, the set of three roller followers 32 stay away from the set of three follower pressing protrusions 17a, respectively, because each roller follower 32 is engaged in the associated rear circumferential slot 5 portion 14e-2 to be positioned in the vicinity of the rear end thereof.

Rotating the third external barrel 15 in the lens barrel advancing direction (upwards as viewed in Figures 60 and 69) causes the set of three rotation transfer groove 10 15f to push the set of three roller followers 32 upwards as viewed in Figures 60 and 69, respectively, to move each roller follower 32 in the associated through-slots 14e from the rear circumferential slot portion 14e-2 to the inclined lead slot portion 14e-3. Since the inclined 15 lead slot portion 14e-3 of each through-slot 14e extends in a direction having both a component in a circumferential direction of the first linear guide ring 14 and a component in the optical axis direction, each roller follower 32 gradually moves forward in the optical 20 axis direction as the roller follower 32 moves in the inclined lead slot portion 14e-3 of the associated through-slot 14e toward the front circumferential slot portion 14e-1. However, as long as the roller follower 32 is in the inclined lead slot portion 14e-3 of the 25 associated through-slot 14e, the roller follower 32 is

still away from the associated pressing protrusion 17a. This means that the set of three roller followers 32 are not at all biased by the set of three follower pressing protrusions 17a, respectively. Nevertheless, no 5 substantial problem arises even if backlash between the set of three roller followers 32 and the set of three through-slots 14e are removed thoroughly since the zoom lens 71 is in the retracted state or the transitional state from the retracted state to the ready-to-photograph state 10 when each roller follower 32 is engaged in the rear circumferential slot portion 14e-2 or the inclined lead slot portion 14e-3 of the associated through-slot 14e, respectively. If anything, the load on the zoom motor 150 decreases with decrease in frictional resistance to 15 each roller follower 32.

If the set of three roller followers 32 move from the inclined lead slot portions 14e-3 of the set of three through-slots 14e to the front circumferential slot portions 14e-1 of the same, respectively, by a further 20 rotation of the third external barrel 15 in the lens barrel advancing direction, the first linear guide ring 14, the third external barrel 15 and the set of three roller followers 32 are positioned as shown in Figures 61 and 70 so that the zoom lens 71 is set at the wide-angle 25 extremity. Since the tip of each follower pressing

protrusion 17a is positioned inside the front circumferential slot portion 14e-1 of the associated radial slot 14 as described above, each roller follower 32 comes into contact with the associated follower 5 pressing protrusion 17a upon entering the associated front circumferential slot portion 14e-1 (see Figures 33, 61 and 70). This causes each follower pressing protrusion 17a to be pressed forward in the optical axis direction by the associated roller follower 32, thus 10 causing the follower-biasing ring spring 17 to be further deformed to make the shape of the set of three forwardly-projecting arc portions 17b become closer to a flat shape. At this time, each roller follower 32 is pressed against a rear guide surface in the associated 15 front circumferential slot portion 14e-1 in the optical axis direction by the resiliency of the follower-biasing ring spring 17 to thereby remove backlash between the set of three roller followers 32 and the set of three through-slots 14e, respectively.

20 Thereafter, even if the set of three roller followers 32 move in the front circumferential slot portions 14e-1 of the set of three through-slots 14e during a zooming operation between the positions shown in Figures 61 and 70 in which the zoom lens 71 is set at 25 the wide-angle extremity and the positions shown in

Figures 62 and 71 in which the zoom lens 71 is set at the telephoto extremity, each roller follower 32 remains in contact with the associated follower pressing protrusion 17a because each roller follower 32 does not move in the 5 associated rotation transfer groove 15f in the optical axis direction when moving in the associated front circumferential slot portion 14e-1 that extend only in a circumferential direction of the first linear guide ring 14. Therefore, in the zooming range of the zoom lens 10 71 in which photographing is possible, the set of three roller followers 32 are always biased rearward in the optical axis direction by the roller spring 17, which achieves a stable positioning of the set of three roller followers 32 with respect to the first linear guide ring 15 14.

Rotating the third external barrel 15 in the lens barrel retracting direction causes the first linear guide ring 14 and the set of three roller followers 32 to operate in the reverse manner to the above described operations. 20 In this reverse operation, each roller follower 32 is disengaged from the associated follower pressing protrusion 17a upon passing a point (wide-angle extremity point) in the associated through-slot 14e which corresponds to the wide-angle extremity of the zoom lens 25 71 (the position of each roller follower 32 in the

associated through-slot 14e in Figure 61). From the wide-angle extremity point down to a point (retracted point) in the associated through-slot 14e which corresponds to the retracted position of the zoom lens 5 71 (the position of each roller follower 32 in the associated through-slot 14e in Figure 60), the set of three roller followers 32 receive no pressure from the set of three follower pressing protrusions 17a, respectively. If the set of three follower pressing 10 protrusions 17a do not apply any pressure to the set of three roller followers 32, the frictional resistance to each roller follower 32 becomes small when moving in the associated through-slot 14e. Consequently, the load on 15 the zoom motor 150 decreases with decrease in frictional resistance to each roller follower 32.

As can be understood from the above descriptions, the set of three follower pressing protrusions 17a, which are respectively fixed at the locations of the set of three roller followers 32 in the optical axis direction in the 20 set of three rotation transfer grooves 15f when the zoom lens 71 is in the ready-to-photograph state, automatically bias the set of three roller followers 32 rearward to press the set of three roller followers 32 against rear guide surfaces of the front circumferential 25 slot portions 14e-1 of the set of three through-slots 14e

immediately after the set of three roller followers 32 which are guided by the inclined lead slot portions 14e-3 of the set of three through-slots 14e to move forward in the optical axis direction reach their respective 5 photographing positions in a rotatable range at an axial fixed position (i.e., in the front circumferential slot portions 14e-1). With this structure, the backlash between the set of three roller followers 32 and the set of three through-slots 14e can be removed by a simple 10 structure using a single biasing member: the follower-biasing ring spring 17. Moreover, the follower-biasing ring spring 17 consumes little space in the zoom lens 71 since the follower-biasing ring spring 17 is a substantially simple annular member disposed along 15 an inner peripheral surface and since the set of three follower pressing protrusions 17a are positioned in the set of three rotation transfer grooves 15f, respectively. Accordingly, in spite of its small and simple structure, the follower-biasing ring spring 17 can make the cam ring 20 11 positioned precisely at a predetermined fixed position in the optical axis direction with stability in the ready-to-photograph state of the zoom lens 71. This insures optical accuracy of the photographing optical system such as the first lens group LG1 and the second 25 lens group LG2. Furthermore, the follower-biasing ring

spring 17 can be removed easily because the set of three forwardly-projecting arc portions 17b are simply held and supported between the frontmost inner flange 15h and the plurality of relative rotation guide projections 15d.

5       The follower-biasing ring spring 17 has not only a function of biasing the set of three roller followers 32 rearward in the optical axis direction to position the cam ring 11 precisely with respect to the first linear guide ring 14 in the optical axis direction, but also a  
10      function of biasing the first linear guide ring 14 rearward in the optical axis direction to give stability to positioning of the first linear guide ring 14 with respect to the third external barrel 15 in the optical axis direction. Although the second plurality of  
15      relative rotation guide projections 14c and the circumferential groove 15e are engaged with each other to be slightly movable relative to each other in the optical axis direction while the plurality of relative rotation guide projections 15d and the circumferential  
20      groove 14d are engaged with each other to be slightly movable relative to each other in the optical axis direction as shown in Figures 69 through 72, both backlash between the second plurality of relative rotation guide projections 14c and the circumferential groove 15e and  
25      backlash between the plurality of relative rotation guide

projections 15d and the circumferential groove 14d are removed since the front end of the first linear guide ring 14 contacts with the follower-biasing ring spring 17 to be biased rearward in the optical axis direction by the 5 follower-biasing ring spring 17. Accordingly, in the case where three annular members: the cam ring 11, the first linear guide ring 14 and the third external barrel 15 are regarded as a rotating-advancing/rotating-retracting unit, all the different backlashes arising in 10 this whole rotating-advancing/rotating-retracting unit can be removed by a single biasing member: the follower-biasing ring spring 17. This achieves a quite simple backlash removing structure.

Figures 73 through 75 show elements of a linear guide 15 structure in section which guides the first external barrel 12 (which supports the first lens group LG1) and the second lens group moving frame 8 (which supports the second lens group LG2) linearly in the optical axis direction without rotating each of the first external 20 barrel 12 and the second lens group moving frame 8 about the lens barrel axis Z0. Figures 76 through 78 show the elements of the linear guide structure in oblique perspective. Figures 73, 74 and 75 show the linear guide structure when the zoom lens 71 is set at the wide-angle 25 extremity, when the zoom lens 71 is set at the telephoto

extremity, and when the zoom lens 71 is in the retracted state, respectively. In each of the cross sectional views in Figures 73 through 75, the elements of the linear guide structure are crosshatched for the purpose of illustration. In addition, in each of the cross sectional views in Figures 73 through 75, among all the rotatable elements only the cam ring is crosshatched by dashed lines for the purpose of illustration.

The cam ring 11 is a double-side grooved cam ring that is provided on an outer peripheral surface thereof with the set of three outer cam grooves 11b for moving the first external barrel 12 in a predetermined moving manner, and that is provided on an inner peripheral surface of the cam ring 11 with the plurality of inner cam grooves 11a (11a-1 and 11a-2) for moving the second lens group moving frame 8 in a predetermined moving manner. Accordingly, the first external barrel 12 is positioned radially outside the cam ring 11 while the second lens group moving frame 8 is positioned radially inside the cam ring 11. On the other hand, the first linear guide ring 14, which is adopted for guiding each of the first external barrel 12 and the second lens group moving frame 8 linearly without rotating each of the first external barrel 12 and the second lens group moving frame 8 about the lens barrel axis Z0, is positioned radially outside

the cam ring 11.

In this linear guide structure having the above described positional relationship among the first linear guide ring 14, the first external barrel 12 and the second lens group moving frame 8, the first linear guide ring 14 directly guides the second external barrel 13 (which serves as a linear guide member for guiding the first external barrel 12 linearly in the optical axis direction without rotating the same about the lens barrel axis Z0) and the second linear guide ring 10 (which serves as a linear guide member for guiding the second lens group moving frame 8 linearly in the optical axis direction without rotating the same about the lens barrel axis Z0) linearly in the optical axis direction without rotating the same about the lens barrel axis Z0. The second external barrel 13 is positioned radially between the cam ring 11 and the first linear guide ring 14, and guided linearly in the optical axis direction without rotating about the lens barrel axis Z0 by engagement of the set of six radial projections 13a, which are formed on an outer peripheral surface of the second external barrel 13, with the set of six second linear guide grooves 14g, respectively. Moreover, the second external barrel 13 guides the first external barrel 12 linearly in the optical axis direction without rotating the same about

the lens barrel axis Z0 by engagement of the set of three linear guide grooves 13b, which are formed on an inner peripheral surface of the second external barrel 13, with the set of three engaging protrusions 12a of the first 5 external barrel 12, respectively. On the other hand, as for the second linear guide ring 10, to make the first linear guide ring 14 guide the second lens group moving frame 8 that is positioned inside the cam ring 11, the ring portion 10b is positioned behind the cam ring 11, 10 the set of three bifurcated projections 10a are formed to project radially outwards from the ring portion 10b to be respectively engaged in the set of three pairs of first linear guide grooves 14f, and the set of three linear guide keys 10c are formed to project forward from the ring 15 portion 10b in the optical axis direction to be respectively engaged in the set of three guide grooves 8a.

In the case of a linear guide structure having conditions similar to conditions of the linear guide structure shown in Figures 73 through 75 that two linearly guided outer and inner movable elements (the first external barrel 12 and the second lens group moving frame 8) are respectively positioned outside and inside a double-side grooved cam ring (the cam ring 11) and that 25 a primary linear guide member (the first linear guide ring

14) of the linear guide structure is positioned outside the cam ring, a secondary linear guide member serving as the outer movable element (which corresponds to the second external barrel 13) is disposed outside the cam ring,  
5 while a linearly guided movable member (which corresponds to the first external barrel 12) which is guided linearly in the optical axis direction without rotating by the secondary linear guide member is provided with a set of linear guide portions for guiding a movable member serving  
10 as the inner movable element (which corresponds to the second lens group moving frame 8) positioned inside the cam ring linearly in the optical axis direction without rotating the same in a conventional zoom lens. In other words, in the linear guide structure of such a  
15 conventional zoom lens, each of the aforementioned set of linear guide portions of the outer movable element extend radially inwards from the outside of the cam ring to the inside of the cam ring to be engaged with the inner movable element through a single path. According to this  
20 type of conventional linear guide structure, the resistance produced due to linear guiding operations of the outer and inner movable elements of the linear guide structure increases when a relative velocity in the optical axis direction between the two linearly guided  
25 movable elements that are respectively positioned

outside and inside the cam ring is fast. In addition, since the inner movable element is indirectly guided linearly in the optical axis direction without rotating via the outer movable element, the inner movable element, 5 in particular, is difficult to be guided linearly in the optical axis direction without rotating with a high degree of travel accuracy.

In contrast to such a conventional linear guide structure, according to the linear guide structure of the 10 zoom lens 71 shown in Figures 73 through 75, the aforementioned resistance problem can be prevented from occurring by the structure wherein the second external barrel 13, which serves as a linear guide member for guiding the first external barrel 12 (positioned outside 15 the cam ring 11) linearly in the optical axis direction without rotating the same about the lens barrel axis Z0, is engaged with the set of six second linear guide grooves 14g while the second linear guide ring 10, which serves 20 as a linear guide member for guiding the second lens group moving frame 8 (positioned inside the cam ring 11) linearly in the optical axis direction without rotating the same about the lens barrel axis Z0, is engaged with the set of three pairs of first linear guide grooves 14f so that the second external barrel 13 and the second linear 25 guide ring 10 are directly guided by the first linear guide

ring 14 through two paths : a first path (inner path) extending from the set of three pairs of first linear guide grooves 14f to the set of three bifurcated projections 10a and a second path (outer path) extending from the set 5 of six second linear guide grooves 14g to the set of six radial projections 13a. Moreover, the first linear guide ring 14 that directly guides each of the second linear guide ring 10 and the second external barrel 13 linearly at the same time is, in effect, reinforced by the second 10 linear guide ring 10 and the second external barrel 13. This structure makes it easy for the linear guide structure to secure sufficient strength.

Furthermore, each pair of first linear guide grooves 14f, which are adopted for guiding the second linear guide 15 ring 10 linearly in the optical axis direction without rotating the same about the lens barrel axis Z0, are formed by using two opposed side walls between which the associated second linear guide groove 14g is formed. This structure is advantageous to make the linear guide 20 structure simple, and does not impair the strength of the first linear guide ring 14 very much.

The relationship between the cam ring 11 and the second lens group moving frame 8 will be hereinafter discussed in detail. As described above, the plurality 25 of inner cam grooves 11a, which are formed on an inner

peripheral surface of the cam ring 11, consist of the set of three front inner cam grooves 11a-1 that are formed at different circumferential positions, and the set of three rear inner cam grooves 11a-2 that are formed at 5 different circumferential positions behind the set of three front inner cam grooves 11a-1 in the optical axis direction. Each rear inner cam groove 11a-2 is formed as a discontinuous cam groove as shown in Figure 17. All the six cam grooves of the cam ring 11: the set of three 10 front inner cam grooves 11a-1 and the set of three rear inner cam grooves 11a-2 trace six reference cam diagrams "VT" having the same shape and size, respectively. Each reference cam diagram VT represents the shape of each cam groove of the set of three front inner cam grooves 11a-1 15 and the set of three rear inner cam grooves 11a-2, and includes a lens-barrel operating section and a lens-barrel assembling/disassembling section, wherein the lens-barrel operating section consists of a zooming section and a lens-barrel retracting section. The 20 lens-barrel operating section serves as a control section which controls movement of the second lens group moving frame 8 with respect to the cam ring 11, and which is to be distinguished from the lens-barrel assembling/disassembling section that is used only when 25 the zoom lens 71 is assembled or disassembled. The

zooming section serves as a control section which controls the movement of the second lens group moving frame 8 with respect to the cam ring 11, especially from a position of the second lens group moving frame 8 which corresponds 5 to the wide-angle extremity of the zoom lens 71 to another position of the second lens group moving frame 8 which corresponds to the telephoto extremity of the zoom lens 71, and which is to be distinguished from the lens-barrel retracting section. If each front inner cam groove 11a-1 10 and the rear inner cam groove 11a-2 positioned therebehind in the optical axis direction are regarded as a pair, it can be said that the cam ring 11 is provided, at regular intervals in a circumferential direction of the cam ring 11, with three pairs of inner cam grooves 11a for guiding 15 the second lens group LG2.

As can be seen in Figure 17, the length of an axial range W1 of the reference cam diagrams VT of the set of three front inner cam grooves 11a-1 in the optical axis direction (the horizontal direction as viewed in Figure 20 17), which is equivalent to an axial range of the reference cam diagrams VT of the set of three rear inner cam grooves 11a-2 in the optical axis direction, is greater than a length W2 of the cam ring 11 in the optical axis direction. The length of the zooming section included in the axial 25 range W1 of the reference cam diagrams VT of the set of

three front inner cam grooves 11a-1 (or the rear inner cam grooves 11a-2) in the optical axis direction is represented by a length W3 shown in Figure 17 which is alone substantially equivalent to the length W2 of the 5 cam ring 11. This means that a set of cam grooves each having a sufficient length will not be obtained for the present embodiment of the cam ring 11 if designed according to a conventional method of formation of cam groove wherein a set of long cam grooves which entirely 10 trace a corresponding set of long cam diagrams are formed on a peripheral surface of a cam ring. According to a cam mechanism of the present embodiment of the zoom lens, a sufficient range of movement of the second lens group moving frame 8 in the optical axis direction can be secured 15 without increasing the length of the cam ring 11 in the optical axis direction. The detail of this cam mechanism will be discussed hereinafter.

Each front inner cam groove 11a-1 does not cover the entire range of the associated reference cam diagram VT 20 while each rear inner cam groove 11a-2 does not cover the entire range of the associated reference cam diagram VT either. A range of each front inner cam groove 11a-1 which is included in the associated reference cam diagram VT is partly different from a range of each rear inner 25 cam groove 11a-2 which is included in the associated

reference cam diagram VT. Each reference cam diagram VT can be roughly divided into four sections: first through fourth sections VT<sub>1</sub> through VT<sub>4</sub>. The first section VT<sub>1</sub> extends in the optical axis direction. The second 5 section VT<sub>2</sub> extends from a first inflection point VT<sub>h</sub> positioned at the rear end of the first section VT<sub>1</sub> to a second inflection point VT<sub>m</sub> positioned behind the first inflection point VT<sub>h</sub> in the optical axis direction. The third section VT<sub>3</sub> extends from the second inflection point 10 VT<sub>m</sub> to a third inflection point VT<sub>n</sub> positioned in front of the second inflection point VT<sub>m</sub> in the optical axis direction. The fourth section VT<sub>4</sub> extends from the third inflection point VT<sub>n</sub>. The fourth section VT<sub>4</sub> is used only when the zoom lens 71 is assembled or disassembled, and 15 is included in both each front inner cam groove 11a-1 and each rear inner cam groove 11a-2. Each front inner cam groove 11a-1 is formed in the vicinity of the front end of the cam ring 11 not to include the entire part of the first section VT<sub>1</sub> and a part of the second section VT<sub>2</sub>, 20 and is formed to include a front end opening R<sub>1</sub> at an intermediate point of the second section VT<sub>2</sub> so that the front end opening R<sub>1</sub> opens on a front end surface of the cam ring 11. On the other hand, each rear inner cam groove 11a-2 is formed in the vicinity of the rear end of the 25 cam ring 11 not to include adjoining portions of the second

section VT2 and the third section VT3 on opposite sides of the second inflection point VTm. In addition, each rear inner cam groove 11a-2 is formed to include a front end opening R4 (which corresponds to the aforementioned 5 front open end section 11a-2x) at the front end of the first section VT1 so that the front end opening R4 opens on a front end surface of the cam ring 11. A missing portion of each front inner cam groove 11a-1 which lies on the associated reference cam diagram VT is included 10 in the associated rear inner cam groove 11a-2 that is positioned behind the front inner cam groove 11a-1 in the optical axis direction, whereas a missing portion of each rear inner cam groove 11a-2 which lies on the associated reference cam diagram VT is included in the associated 15 front inner cam groove 11a-1 that is positioned in front of the rear inner cam groove 11a-2 in the optical axis direction. Namely, if each front inner cam groove 11a-1 and the associated rear inner cam groove 11a-2 are combined into a single cam groove, this signal cam groove 20 will include the entire part of one reference cam diagram VT. In other words, one of each front inner cam groove 11a-1 and the associated rear inner cam groove 11a-2 is complemented by the other. The width of each front inner cam groove 11a-1 and the width of each rear inner cam 25 groove 11a-2 are the same.

Meanwhile, as shown in Figure 19, the plurality of cam followers 8b, which are respectively engaged in the plurality of inner cam grooves 11a, consist of the set of three front cam followers 8b-1 that are formed at 5 different circumferential positions, and the set of three rear cam followers 8b-2 that are formed at different circumferential positions behind the set of three front cam followers 8b-1 in the optical axis direction, wherein each front cam follower 8b-1 and the rear cam follower 10 8b-2 positioned therebehind in the optical axis direction are provided as a pair in a manner similar to each pair of inner cam grooves 11a. The space between the set of three front cam followers 8b-1 and the set of three rear cam followers 8b-2 in the optical axis direction is 15 determined so that the set of three front cam followers 8b-1 are respectively engaged in the set of three front inner cam grooves 11a-1 and so that the set of three rear cam followers 8b-2 are respectively engaged in the set of three rear inner cam grooves 11a-2. The diameter of 20 each front cam follower 8b-1 and the diameter of each rear cam follower 8b-2 are the same.

Figure 79 shows the positional relationship between the plurality of inner cam grooves 11a and the plurality of cam followers 8b when the zoom lens 71 is the retracted 25 state as shown in Figure 10. When the zoom lens 71 is

the retracted state, each front cam follower 8b-1 is positioned in the associated front inner cam groove 11a-1 in the vicinity of the third inflection point VTn thereof while each rear cam follower 8b-2 is positioned in the 5 associated rear inner cam groove 11a-2 in the vicinity of the third inflection point VTn thereof. Since each front inner cam groove 11a-1 includes a portion thereof in the vicinity of the third inflection point VTn while each rear inner cam groove 11a-2 includes a portion 10 thereof in the vicinity of the third inflection point VTn, each front cam follower 8b-1 and each rear cam follower 8b-2 are engaged in the associated front inner cam groove 11a-1 and the associated rear inner cam groove 11a-2, respectively.

15        Rotating the cam ring 11 in the lens barrel advancing direction (upwards as viewed in Figure 79) in the retracted state shown in Figure 79 causes each front cam follower 8b-1 and each rear cam follower 8b-2 to be guided rearward in the optical axis direction to move on the third 20 section VT3 toward the second inflection point VTm by the associated front inner cam groove 11a-1 and the associated rear inner cam groove 11a-2, respectively. In the middle of this movement of each cam follower 8b, each rear cam follower 8b-2 is disengaged from the associated rear inner 25 cam groove 11a-2 through a first rear end opening R3

thereof which opens on a rear end surface of the cam ring 11 because each rear inner cam groove 11a-2 does not include adjoining portions of the second section VT2 and the third section VT3 on opposite sides of the second 5 inflection point VTm. At this time, each front cam follower 8b-1 remains engaged in the associated front inner cam groove 11a-1 since each front inner cam groove 11a-1 includes a rear portion thereof in the optical axis direction which corresponds to the missing rear portion 10 of each rear inner cam groove 11a-2 in the optical axis direction. On or after each rear cam follower 8b-2 being disengaged from the associated rear inner cam groove 11a-2 through the first rear end opening R3 thereof, the second lens group moving frame 8 moves in the optical axis 15 direction by rotation of the cam ring 11 only due to engagement of each front cam follower 8b-1 with the associated front inner cam groove 11a-1.

Figure 80 shows the positional relationship between the plurality of inner cam grooves 11a and the plurality 20 of cam followers 8b when the zoom lens 71 is in the state shown below the photographing lens axis Z1 in Figure 9 in which the zoom lens 71 is set at the wide-angle extremity. In this state shown below the photographing lens axis Z1 in Figure 9, each front cam follower 8b-1 is positioned in the second section VT2 slightly beyond 25

the second inflection point VTm. Although each rear cam follower 8b-2 is currently disengaged from the associated rear inner cam groove 11a-2 through the first rear end opening R3 thereof as described above, each rear cam follower 8b-2 remains positioned on the associated reference cam diagram VT because the associated front cam follower 8b-1 positioned in front of the rear cam follower 8b-2 remains engaged in the associated front inner cam groove 11a-1.

Rotating the cam ring 11 in the lens barrel advancing direction (upward as viewed in Figure 80) in the state shown in Figure 80, in which the zoom lens 71 is set at the wide-angle extremity, causes each front cam follower 8b-1 to be guided forward in the optical axis direction to move on the second section VT2 toward the first section VT1 by the associated front inner cam groove 11a-1. With this forward movement of each front cam follower 8b-1, each rear cam follower 8b-2 which is currently disengaged from the associated rear inner cam groove 11a-2 moves on the second section VT2 toward the first section VT1, and shortly enters a second rear end opening R2 formed on a rear end surface of the cam ring 11 to be re-engaged in the associated rear inner cam groove 11a-2. On or after this re-engagement of each rear cam follower 8b-2 with the associated rear inner cam groove 11a-2, each front

cam follower 8b-1 and each rear cam follower 8b-2 are guided by the associated front inner cam groove 11a-1 and the associated rear inner cam groove 11a-2, respectively. However, shortly after the re-engagement of each rear 5 cam follower 8b-2 with the associated rear inner cam groove 11a-2, each front cam follower 8b-1 is disengaged from the associated front inner cam groove 11a-1 through the front end opening R1 because a front end portion of each front inner cam groove 11a-1 which lies on the 10 associated reference cam diagram VT is missing. At this time, each rear cam follower 8b-2 remains engaged in the associated rear inner cam groove 11a-2 since each rear inner cam groove 11a-2 includes a front end portion thereof in the optical axis direction which corresponds 15 to the missing front end portion of each front inner cam groove 11a-1 in the optical axis direction. On or after each front cam follower 8b-1 being disengaged from the associated front inner cam groove 11a-1 through the front end opening R1 thereof, the second lens group moving frame 20 8 moves in the optical axis direction by rotation of the cam ring 11 only due to engagement of each rear cam follower 8b-2 with the associated rear inner cam groove 11a-2.

Figure 81 shows the positional relationship between 25 the plurality of inner cam grooves 11a and the plurality

of cam followers 8b when the zoom lens 71 is in the state shown above the photographing lens axis Z1 in Figure 9 in which the zoom lens 71 is set at the telephoto extremity. In this state shown above the photographing lens axis Z1 5 in Figure 9, each front cam follower 8b-1 is positioned in the second section VT2 in the vicinity of the first inflection point VTh. Although each front cam follower 8b-1 is currently disengaged from the associated front inner cam groove 11a-1 through the front end opening R1 10 thereof as described above, each front cam follower 8b-1 remains on the associated reference cam diagram VT because the associated rear cam follower 8b-2 positioned behind the front cam follower 8b-1 remains engaged in the associated rear inner cam groove 11a-2.

15 Further rotating the cam ring 11 in the lens barrel advancing direction (upward as viewed in Figure 81) in the state shown in Figure 81, in which the zoom lens 71 is set at the telephoto extremity, causes each rear cam follower 8b-2 to enter the first section VT1 via the first 20 inflection point VTh as shown in Figure 82. At this time, each front cam follower 8b-1 has been disengaged from the associated front inner cam groove 11a-1, and merely each rear cam follower 8b-2 is engaged in a front end portion (the first section VT1) of the associated rear inner cam 25 groove 11a-2 which extends in the optical axis direction,

so that the second lens group moving frame 8 can be removed from the cam ring 11 from the front thereof in the optical axis direction to remove each rear cam follower 8b-2 from the associated rear inner cam groove 11a-2 via the front 5 end opening R4. Accordingly, Figure 82 shows a state where the cam ring 11 and the second lens group moving frame 8 are put together or removed from each other.

As described above, in the present embodiment of the zoom lens, each pair of cam grooves having the same 10 reference cam diagram VT, i.e., each front inner cam groove 11a-1 and the associated rear inner cam groove 11a-2 are formed at different points in the optical axis direction on the cam ring 11; moreover, each front inner cam groove 11a-1 and the associated rear inner cam groove 11a-2 are formed so that one end of the front inner cam groove 11a-1 opens on a front end surface of the cam ring 11 without the front inner cam groove 11a-1 including the entire part of the associated reference cam diagram VT and so that one end of the rear inner cam groove 11a-20 2 opens on a rear end surface of the cam ring 11 without the rear inner cam groove 11a-2 including the entire part of the associated reference cam diagram VT; and furthermore, one of the front inner cam groove 11a-1 and the rear inner cam groove 11a-2 is complemented by the 25 other to include the entire part of one reference cam

diagram VT. In addition, only each rear cam follower 8b-2 is engaged in the associated rear inner cam groove 11a-2 when the second lens group moving frame 8 is positioned at a front limit for the axial movement thereof with respect to the cam ring 11 (which corresponds to the state shown above the photographing lens axis Z1 in Figure 9 in which the zoom lens 71 is set at the telephoto extremity), while only each front cam follower 8b-1 is engaged in the associated front inner cam groove 11a-1 when the second lens group moving frame 8 is positioned at a rear limit for the axial movement thereof with respect to the cam ring 11 (which corresponds to a state shown below the photographing lens axis Z1 in Figure 9 in which the zoom lens 71 is set at the wide-angle extremity).

With this structure, a sufficient range of movement of the second lens group moving frame 8 in the optical axis direction which is greater than the range of movement of the cam ring 11 in the optical axis direction is achieved. Namely, the length of the cam ring 11 in the optical axis direction can be reduced without sacrificing the range of movement of the second lens group moving frame 8, which supports the second lens group LG2 via the second lens frame 6, in the optical axis direction.

In a typical cam mechanism having a rotatable cam ring on which a set of cam grooves are formed and a driven

member having a set of cam followers which are respectively engaged in the set of cam grooves, the amount of movement of each cam follower per unit of rotation of the cam ring decreases to thereby make it possible to move  
5 the driven member with a higher degree of positioning accuracy by rotation of the cam ring as the degree of inclination of each cam groove on the cam ring relative to the rotational direction of the cam ring becomes small, i.e., as the direction of extension of each cam groove  
10 becomes close to a circumferential direction of the cam ring. In addition, the degree of resistance to the cam ring when it rotates becomes smaller to thereby make the driving torque for rotating the cam ring smaller as the degree of inclination of each cam groove on the cam ring  
15 relative to the rotational direction of the cam ring becomes small. A reduction of the driving torque results in an increase in durability of elements of the cam mechanism and a decrease in power consumption of the motor for driving the cam ring, and makes it possible to adopt  
20 a small motor for driving the cam ring to downsize the lens barrel. Although it is known that the actual contours of the cam grooves are determined in consideration of various factors such as the effective area of an outer or inner peripheral surface of the cam  
25 ring and the maximum angle of rotation of the cam ring,

it is generally the case that the cam grooves have the above described tendencies.

As described above, it can be said that the cam ring 11 is provided, at regular intervals in a circumferential direction of the cam ring 11, with three pairs (groups) of inner cam grooves 11a for guiding the second lens group LG2 if each front inner cam groove 11a-1 and the rear inner cam groove 11a-2 positioned therebehind in the optical axis direction are regarded as a pair (group). Similarly, 10 it can be said that the second lens group moving frame 8 is provided, at regular intervals in a circumferential direction thereof, with three pairs (groups) of cam followers 8b if each front rear cam follower 8b-1 and the rear cam follower 8b-2, positioned therebehind in the 15 optical axis direction, are regarded as a pair (group). As for the reference cam diagrams VT of the plurality of inner cam grooves 11a, provided only three of the reference cam diagrams VT are to be arranged on an inner peripheral surface of the cam ring 11 along a line thereon 20 extending in a circumferential direction of the cam ring 11, the three reference cam diagrams VT will not interfere with one another on the inner peripheral surface of the cam ring 11 though each reference cam diagram VT has an undulating shape. However, in the present embodiment of 25 the zoom lens, in order to shorten the length of the cam

ring 11 in the optical axis direction to thereby minimize the length of the zoom lens 71, six reference cam diagrams VT need to be arranged on the inner peripheral surface of the cam ring 11 in total because the set of three front 5 inner cam grooves 11a-1 and the corresponding set of three rear cam grooves (three discontinuous rear cam grooves) 11a-2, six cam grooves in total, need to be formed separately on front and rear portions on the inner peripheral surface of the cam ring 11 in the optical axis 10 direction, respectively. Although each of the six inner cam grooves 11a-1 and 11a-2 is shorter than the reference cam diagram VT, it is generally the case that the space for the inner cam grooves 11a-1 and 11a-2 on the cam ring 11 becomes tighter as the number of the cam grooves is 15 great. Therefore, if the number of the cam grooves is great, it is difficult to form the cam grooves on the cam ring without making the cam grooves interfering with each other. To prevent this problem from occurring, it has been conventionally practiced to increase the degree of 20 inclination of each cam groove relative to the rotational direction of the cam ring (i.e., to make the direction of extension of each cam groove close to a circumferential direction of the cam ring) or to increase the diameter of the cam ring to enlarge the area of a peripheral surface 25 of the cam ring on which the cam grooves are formed.

However, increasing the degree of inclination of each cam groove is not desirable in terms of the attainment of a high degree of positioning accuracy in driving a driven member driven by the cam ring and also a saving in the 5 driving torque for rotating the cam ring, and increasing the diameter of the cam ring is not desirable either because the zoom lens will be increased in size.

In contrast to such conventional practices, according to the present embodiment of the zoom lens, the 10 inventor of the present invention has found the fact that a substantial performance characteristics of the cam mechanism is maintained even if each front inner cam groove 11a-1 intersects one of the set of three rear inner cam grooves 11a-2, as long as the reference cam diagrams 15 VT of the six inner cam grooves 11a (11a-1 and 11a-2) are the same while one cam follower of each pair of cam followers (each front cam follower 8b-1 and the associated rear cam follower 8b-2) remains engaged in the associated inner cam groove 11a-1 or 11a-2 at the moment at which 20 the other cam follower 8b-1 or 8b-2 passes through a point of intersection between the front inner cam groove 11a-1 and the rear inner cam groove 11a-2. On the basis of this fact, each front inner cam groove 11a-1 and adjacent one 25 of the set of three rear inner cam grooves 11a-2, which are adjacent to each other in a circumferential direction

of the cam ring 11, are formed to intersect each other intentionally without changing the shape of each reference cam diagram VT and without increasing the diameter of the cam ring 11. More specifically, if the  
5 three pairs of inner cam grooves 11a are respectively treated as a first pair of cam grooves G1, a second pair of cam grooves G2 and a third pair of cam grooves G3 as shown in Figure 17, the front inner cam groove 11a-1 of the first pair G1 and the rear inner cam groove 11a-2 of  
10 the second pair G2, which are adjacent to each other in a circumferential direction of the cam ring 11, intersect each other, the first inner cam groove 11a-1 of the second pair G2 and the rear inner cam groove 11a-2 of the third pair G3, which are adjacent to each other in a  
15 circumferential direction of the cam ring 11, intersect each other, and the front inner cam groove 11a-1 of the third pair G3 and the rear inner cam groove 11a-2 of the first pair G1, which are adjacent to each other in a circumferential direction of the cam ring 11, intersect  
20 each other.

To make one cam follower of each pair of cam followers (each front cam follower 8b-1 and the associated rear cam follower 8b-2) remain properly engaged in the associated inner cam groove 11a-1 or 11a-2 at the moment  
25 at which the other cam follower 8b-1 or 8b-2 passes through

the point of intersection between the front inner cam groove 11a-1 and the rear inner cam groove 11a-2, the front inner cam groove 11a-1 and the rear inner cam groove 11a-2 of each pair of the first through third pairs of cam grooves G1, G2 and G3 are formed not only at different axial positions in the optical axis direction but also at different circumferential positions in a circumferential direction of the cam ring 11. The positional difference in a circumferential direction of the cam ring 11 between the front inner cam groove 11a-1 and the rear inner cam groove 11a-2 of each pair of the first through third pairs of cam grooves G1, G2 and G3 is indicated by "HJ" in Figure 17. This positional difference HJ changes the point of intersection between the front inner cam groove 11a-1 and the rear inner cam groove 11a-2 in a circumferential direction of the cam ring 11. Consequently, in each pair of the first through third pairs of cam grooves G1, G2 and G3, the point of intersection is positioned in the vicinity of the second inflection point VTm on the third section VT3 of the front inner cam groove 11a-1, and also in the vicinity of the first inflection point VTh the front end opening R4 (the front open end section 11a-2x) at the front end of the first section VT1.

As can be understood from the above descriptions,

at the moment at which the set of three front cam followers 8b-1 pass through the points of intersection in the set of three front inner cam grooves 11a-1, the set of three rear cam followers 8b-2 remain engaged in the set of three 5 rear inner cam grooves 11a-2 so that the set of three front cam followers 8b-1 can pass through the points of intersection without being disengaged from the set of three front inner cam grooves 11a-1, respectively (see Figure 83), by forming the set of three front inner cam grooves 11a-1 and the corresponding set of three rear inner cam grooves 11a-2 in the above described manner. 10 Although each front inner cam groove 11a-1 has the point of intersection therein between the zooming section and the lens-barrel retracting section, i.e. in the lens-barrel operating section, the lens barrel 71 can securely 15 be advanced and retracted with the cam ring 11 regardless of the existence of a section of each front inner cam groove 11a-1 which includes the point of intersection therein.

20       Although each front cam follower 8b-1 is already disengaged from the associated front inner cam groove 11a-1 when each rear cam follower 8b-2 reaches the point of intersection in the rear inner cam groove 11a-2 as shown in Figure 82, this point of intersection is positioned 25 in the lens-barrel assembling/disassembling section,

i.e., out of the lens-barrel operating section, so that each rear cam follower 8b-2 is not in a state where it receives torque from the cam ring 11. Accordingly, as for the set of three rear inner cam grooves 11a-2, a 5 possibility of each rear cam follower 8b-2 being disengaged from the associated rear inner cam groove 11a-2 at the point of intersection therein does not have to be taken into consideration when the zoom lens 71 is in the ready-to-photograph state.

10           The point of intersection in each front inner cam groove 11a-1 is in a section thereof through which the associated front cam follower 8b-1 passes between a state shown in Figure 79 in which the zoom lens 71 is in the retracted state and a state shown in Figure 80 in which 15 the zoom lens 71 is in the wide-angle extremity, while the point of intersection in each rear inner cam groove 11a-2 is in the lens-barrel assembling/disassembling section as described above. Therefore, either each front inner cam groove 11a-1 or each rear inner cam groove 11a-2 20 does not have the point of intersection therein in the zooming range between the wide-angle extremity and the telephoto extremity. This makes it possible to insure a high degree of positioning accuracy in driving the second lens group LG2 during a zooming operation of the 25 zoom lens 71 regardless of the existence of the point of

intersection between cam grooves.

Namely, the timing of engagement or disengagement of each cam follower in or from the associated cam groove can be varied by adjusting the aforementioned positional difference b. Moreover, the point of intersection between two cam grooves (11a-1 and 11a-2) can be positioned in an appropriate section therein which does not affect any adverse effect on a zooming operation by adjusting the aforementioned positional difference b.

As can be understood from the above descriptions, in the present embodiment of the zoom lens, each front inner cam groove 11a-1 and each rear inner cam groove 11a-2 are successfully arranged on the inner peripheral surface of the cam ring 11 in a space-saving fashion without deteriorating the positioning accuracy in driving the second lens group LG2 by making each front inner cam groove 11a-1 and adjacent one of the set of three rear inner cam grooves 11a-2, which are adjacent to each other in a circumferential direction of the cam ring 11, intersect each other intentionally and further by forming each front inner cam groove 11a-1 and the associated rear inner cam groove 11a-2 not only at different axial positions in the optical axis direction but also at different circumferential positions in a circumferential direction of the cam ring 11. Accordingly, not only the length of

the cam ring 11 in the optical axis direction but also the diameter of the cam ring 11 can be reduced.

The second lens group moving frame 8 is movable in the optical axis direction by a comparatively great amount 5 of movement as compared with the length of the zoom lens by the above described structure of the cam ring 11. However, it is conventionally the case that it is difficult to guide such a moving member the moving range of which is great linearly in a direction of an optical 10 axis without rotating the moving member about the optical axis by a small linear guide structure. In the present embodiment of the zoom lens, the second lens group moving frame 8 can be guided linearly in the optical axis direction without rotating about the lens barrel axis Z0 15 with reliability, without increasing the size of the second lens group moving frame 8.

As can be seen from Figures 73 through 75 and 79 through 82, the second linear guide ring 10 does not move in the optical axis direction relative to the cam ring 20 11. This is because the discontinuous outer edge of the ring portion 10b of the second linear guide ring 10 is engaged in the discontinuous circumferential groove 11e of the cam ring 11 to be rotatable about the lens barrel axis Z0 relative to the cam ring 11 and to be immovable 25 relative to the cam ring 11 in the optical axis direction.

On the other hand, in the operating range of the zoom lens 71 from the retracted position to the telephoto extremity via the wide-angle extremity, the second lens group moving frame 8 is positioned at the rear limit for the axial movement thereof with respect to the cam ring 11 when the zoom lens 71 is set at a focal length in the vicinity of the wide-angle extremity, while the second lens group moving frame 8 is positioned at the front limit for the axial movement thereof with respect to the cam ring 11 when the zoom lens 71 is set at the telephoto extremity.

More specifically, the second lens group moving frame 8 is positioned at the rear limit for the axial movement thereof with respect to the cam ring 11 when each front cam follower 8b-1 and each rear cam follower 8b-2 are positioned on the second inflection point VT<sub>m</sub> of the associated front inner cam groove 11a-1 and the second inflection point VT<sub>m</sub> of the associated rear inner cam groove 11a-2, respectively, namely, when each front cam follower 8b-1 and each rear cam follower 8b-2 are each positioned in close vicinity of its wide-angle position between this wide-angle position and its retracted position.

As for the second linear guide ring 10, the set of three linear guide keys 10c project forward in the optical axis direction from the ring portion 10b, whereas the rear

end of the second lens group moving frame 8 projects rearward, beyond the ring portion 10b of the second linear guide ring 10, when the zoom lens 71 is set at the wide-angle extremity as shown in Figures 73 and 80. To 5 allow the second lens group moving frame 8 having such a structure to move in the optical axis direction with respect to the second linear guide ring 10, the ring portion 10b of the second linear guide ring 10 is provided with a central aperture 10b-T (see Figure 88) which has 10 a diameter allowing the second lens group moving frame 8 to pass therethrough. The set of three linear guide keys 10c are positioned to project forward through the central aperture 10b-T. In other words, the set of three linear guide keys 10c are formed on the second linear guide 15 ring 10 at radial positions not interfering with the ring portion 10b. Front and rear ends of each guide groove 8a that is formed on the second lens group moving frame 8 are open on front and rear end surfaces of the second lens group moving frame 8 so that the associated linear 20 guide key 10c can project forward and rearward from the front and the rear of the second lens group moving frame 8, respectively.

Therefore, the second lens group moving frame 8 does not interfere with the ring portion 10b of the second 25 linear guide ring 10 wherever the second lens group moving

frame 8 is positioned relative to the second linear guide ring 10 in the optical axis direction. This makes it possible to utilize the full ranges of each linear guide key 10c and each guide groove 8a as sliding parts for 5 guiding the second lens group moving frame 8 linearly without rotating the same about the lens barrel axis Z0. For instance, in the state shown in Figures 84 and 85 showing the positional relationship between the second lens group moving frame 8 and the second linear guide ring 10 when the zoom lens 71 is set at the wide-angle extremity (i.e., when the second lens group moving frame 8 is positioned at its rear limit for the axial movement thereof with respect to the second linear guide ring 10), approximately a rear half of the second lens group moving 15 frame 8 projects rearward from the ring portion 10b through the central aperture 10b-T in the optical axis direction, and a rear portion of each linear guide key 10c in the vicinity of the rear end thereof in the optical axis direction is engaged with a front portion of the 20 associated guide groove 8a in the vicinity of the front end thereof in the optical axis direction. In addition, the front end of each linear guide key 10c projects forward from the associated guide groove 8a. Assuming that each 25 linear guide key 10c is not positioned radially inside the ring portion 10b but projects forward directly from

the front of the ring portion 10b unlike the present embodiment of the zoom lens, the second lens group moving frame 8 will not be capable of moving rearward beyond the position thereof shown in Figures 84 and 85 since the 5 second lens group moving frame 8 will be prevented from moving rearward upon contacting with the ring portion 10b.

Thereafter, if the zoom lens 71 changes its focal length from the wide-angle extremity to the telephoto extremity, a rear portion of the second lens group moving 10 frame 8 which is positioned behind the ring portion 10b in the optical axis direction when the zoom lens 71 is set at the wide-angle extremity has been moved forward from the ring portion 10b through the central aperture 10b-T in the optical axis direction so that the entire 15 part of the second lens group moving frame 8 is positioned in front of the ring portion 10b as shown in Figures 86 and 87. As a result, the rear end of each linear guide key 10c projects rearward from the associated guide groove 8a so that only a front portion of each linear guide key 20 10c and a rear portion of the associated guide groove 8a are engaged with each other in the optical axis direction. During the movement of the second lens group moving frame 8 in the optical axis direction when the zoom lens 71 changes its focal length from the wide-angle extremity 25 to the telephoto extremity, the set of three linear guide

keys 10c remain engaged in the set of three guide grooves 8a so that the second lens group moving frame 8 is securely guided linearly in the optical axis direction without rotating about the lens barrel axis Z0.

5        In the case where only a linear guiding function between the second linear guide ring 10 and the second lens group moving frame 8 is considered, almost the entire portion of each linear guide key 10c in the optical axis direction and almost the entire portion of each guide 10 groove 8a in the optical axis direction can be utilized theoretically as effective guide portions which can remain engaged with each other until just before being disengaged from each other. However, each of the respective effective guide portions is determined with 15 a margin so as not to deteriorate the stability of engagement of the set of three linear guide keys 10c with the set of three guide grooves 8a. For instance, in the state shown in Figures 84 and 85 in which the zoom lens 71 is set at the wide-angle extremity, the relative 20 position between the set of three linear guide keys 10c and the set of three guide grooves 8a shown in Figures 84 and 85 corresponds to the wide-angle extremity of the zoom lens 71 to ensure a sufficient amount of engagement between the set of three linear guide keys 10c and the 25 set of three guide grooves 8a though each guide groove

8a still has room for the associated linear guide key 10c to further move rearward in the optical axis direction. Although the second lens group moving frame 8 is positioned at the rear limit for the axial movement thereof with respect to the cam ring 11 when each front cam follower 8b-1 and each rear cam follower 8b-2 are positioned on the second inflection point V<sub>Tm</sub> of the associated front inner cam groove 11a-1 and the second inflection point V<sub>Tm</sub> of the associated rear inner cam groove 11a-2, respectively, namely, when each front cam follower 8b-1 and each rear cam follower 8b-2 are each positioned in close vicinity of its wide-angle position between this wide-angle position and its retracted position as described above, a sufficient amount of engagement of the set of three linear guide keys 10c with the set of three guide grooves 8a is secured even when the second lens group moving frame 8 is positioned at such a rear limit for the axial movement thereof with respect to the cam ring 11. In the state shown in Figures 86 and 87 in which the zoom lens 71 is set at the telephoto extremity, the second lens group moving frame 8 can further move forward to the second linear guide ring 10 when the zoom lens 71 is in the assembling/disassembling state, each linear guide key 10c remains engaged in the associated guide groove 8a in the

assembling/disassembling state (see Figure 82).

As described above, to increase the maximum amount of movement of the second lens group moving frame 8 relative to the cam ring 11, the plurality of cam followers 5 8b of the second lens group moving frame 8 include the set of three front cam followers 8b-1, which are formed at different circumferential positions to be respectively engaged in the set of three front inner cam grooves 11a-1, and a set of three rear cam followers 8b-2, 10 which are formed at different circumferential positions behind the set of three front cam followers 8b-1 to be respectively engaged in the set of three rear inner cam grooves 11a-2. The set of three rear cam followers 8b-2 move rearward from the ring portion 10b when the zoom lens 15 71 is driven from the retracted position to the wide-angle extremity, and move forward from the ring portion 10b when the zoom lens 71 is driven from the wide-angle extremity to the telephoto extremity. The set of three rear cam followers 8b-2 are positioned behind the ring portion 10b when disengaged from the set of three rear inner cam grooves 11a-2 from the first rear end openings R3 or the second rear end openings R2, respectively. The ring portion 10b is provided on an inner edge thereof at different circumferential positions with three radial recesses 10e through which the set of three rear cam

followers 8b-2 can pass the ring portion 10b in the optical axis direction, respectively, (see Figures 88 and 89).

The three radial recesses 10e are formed on the ring portion 10b to be aligned with the set of three rear cam followers 8b-2 in the optical axis direction when engaged therewith, respectively. Therefore, at the time when each rear cam follower 8b-2 reaches the first rear end opening R3 of the associated rear inner cam groove 11a-2 in the course of rearward movement of the rear cam follower 10 8b-2 with respect to the second linear guide ring 10 from the retracted position shown in Figure 79 toward a position shown in Figure 80 which corresponds to the wide-angle extremity of the zoom lens 71, the three radial recesses 10e are also aligned with the three first rear 15 end openings R3 in the optical axis direction to allow the set of three rear cam followers 8b-2 to move rearward beyond the ring portion 10b through the three radial recesses 10e and the three first rear end openings R3, respectively. Thereafter, each rear cam follower 8b-20 changes the direction of movement thereof at the second inflection point VT<sub>m</sub> of the associated reference cam diagram VT to then move forward in the optical axis direction, and remains positioned behind the ring portion 10b until reaching the second rear end opening R2 of the 25 associated rear inner cam groove 11a-2 as shown in Figures

80 and 85. Upon each rear cam follower 8b-2 reaching the second rear end opening R2 of the associated rear inner cam groove 11a-2 when moving forward further from the position shown in Figure 80 which corresponds to the 5 wide-angle extremity of the zoom lens 71, the three radial recesses 10e are aligned with the three second rear end openings R2 in the optical axis direction this time to allow the set of three rear cam followers 8b-2 to enter the set of three rear inner cam grooves 11a-2 through the 10 three radial recesses 10e and the three second rear end openings R2, respectively. Accordingly, the ring portion 10b of the second linear guide ring 10 does not interfere with movement of the set of three rear cam followers 8b-2 because the ring portion 10b is provided 15 with the three radial recesses 10e, through which the set of three rear cam followers 8b-2 can pass the ring portion 10b in the optical axis direction, respectively.

As can be understood from the above descriptions, according to the above described linear guide structure, 20 the second lens group moving frame 8, the moving range of which in the optical axis direction is comparatively great, can be securely guided linearly without rotating about the lens barrel axis Z0 by the second linear guide ring 10 without the ring portion 10b interfering with the 25 second lens group moving frame 8. As can be seen from

Figures 79 through 82, the present embodiment of the linear guide structure cannot be greater than a conventional linear guide structure because the length of each linear guide key 10c is smaller than the length 5 of the cam ring 11 in the optical axis direction.

The support structure between the second linear guide ring 10 and the second lens group moving frame 8 that are positioned inside the cam ring 11 has been discussed above. The support structure between the first 10 external barrel 12 and the second external barrel 13 that are positioned outside the cam ring 11 will be discussed hereinafter.

The cam ring 11 and the first external barrel 12 are arranged concentrically about the lens barrel axis Z0. 15 The first external barrel 12 moves in the optical axis direction in a predetermined moving manner by engagement of the set of three cam followers 31, which project radially inwards from the first external barrel 12, with the set of three outer cam grooves 11b, which are formed 20 on an outer peripheral surface of the cam ring 11. Figures 90 through 100 show positional relationships between the set of three cam followers 31 and the set of three outer cam grooves 11b. In Figures 90 through 100, the first external barrel 12 is shown by one-dot chain 25 lines while the second external barrel 13 is shown by

two-dot chain lines.

As shown in Figure 16, each outer cam groove 11b, which is formed on an outer peripheral surface of the cam ring 11, is provided at one end (front end) thereof with 5 a front end opening section 11b-X which is open on a front end surface of the cam ring 11, and is provided at the other end (rear end) thereof with a rear end opening section 11b-Y which is open on a rear end surface of the cam ring 11. Accordingly, the opposite ends of each outer 10 cam groove 11b are respectively formed as open ends. Each outer cam groove 11b is provided between the front end opening section 11b-X and the rear end opening section 11b-Y with an inclined lead section 11b-L which extends linearly obliquely from the rear end opening section 11b-Y 15 toward the front of the optical axis direction, and a curved section 11b-Z which is positioned between the inclined lead section 11b-L and the front end opening section 11b-X to be curved rearward (downward as viewed in Figure 16) in the optical axis direction. A zooming 20 section for changing the focal length of the zoom lens 71 before picture taking is included in the curved section 11b-Z of each outer cam groove 11b. As shown in Figures 94 through 100, the set of three cam followers 31 can be inserted into and removed from the set of three outer cam 25 grooves 11b through the front end opening sections 11b-X

thereof, respectively. When the zoom lens 71 is set at the telephoto extremity, each cam follower 31 is positioned in the associated curved section 11b-Z in the vicinity of the front end opening section 11b-X as shown 5 in Figures 93 and 99. When the zoom lens 71 is set at the wide-angle extremity, each cam follower 31 is positioned in the associated curved section 11b-Z in the vicinity of inclined lead section 11b-L as shown in Figures 92 and 98.

10        In the state shown in Figures 90 and 95 in which the zoom lens 71 is in the retracted state, each cam follower 31 is in the associated rear end opening section 11b-Y. The width of the rear end opening section 11b-Y of each outer cam groove 11b is greater than the width of 15 the inclined lead section 11b-L and the width of the curved section 11b-Z in a circumferential direction of the cam ring 11 so that each cam follower 31 is allowed to move in a circumferential direction of the cam ring 11 to some extent in the associated rear end opening section 11b-Y.  
20        Although the rear end opening section 11b-Y of each outer cam groove 11b is open at the rear of the cam ring 11, the set of three cam followers 31 do not come off the set of three outer cam grooves 11b through the three rear end opening sections 11b-Y, respectively, because the cam 25 ring 11 is provided with at least one stop portion which

determines a rear limit for the axial movement of the first external barrel 12 with respect to the cam ring 11.

More specifically, the cam ring 11 is provided, at the front end thereof at different circumferential positions, with a set of three front projecting portions 11f which project forward in the optical axis direction as shown in Figure 16. The aforementioned set of three external protuberances 11g, which are formed on the cam ring 11 to project radially outwards, are formed behind the set of three front projecting portions 11f in the optical axis direction, respectively. Each external protuberance 11g is provided with a corresponding section of the discontinuous circumferential groove 11c. The set of three roller followers 32 are fixed onto the set of three external protuberances 11g by the three set screws 32a, respectively. The set of three front projecting portions 11f are provided at the front ends thereof with a set of three front stop surfaces 11s-1, respectively, which lie in a plane orthogonal to the photographing optical axis Z1. The set of three external protuberances 11g are provided at the front ends thereof with a set of three rear stop surfaces 11s-2 which lie in a plane orthogonal to the photographing optical axis Z1. On the other hand, as shown in Figure 21, the first external barrel 12 is provided on an inner peripheral surface

thereof with a set of three protuberances, and a set of three front stop surfaces 12s-1 are provided at the rear end surface of the protuberances to correspond (oppose) to the set of three front stop surfaces 11s-1 so that the  
5 set of three front stop surfaces 12s-1 can come into contact with the set of three front stop surfaces 11s-1, respectively. The first external barrel 12 is provided at the rear end thereof with a set of three rear stop surfaces 12s-2 to correspond to the set of three rear stop  
10 surfaces 11s-2 so that the set of three rear stop surfaces 12s-2 can come into contact with the set of three rear stop surfaces 11s-2, respectively. Each front stop surface 12s-1 and each rear stop surface 12s-2 are parallel to each front stop surface 11s-1 and each rear  
15 stop surface 11s-2, respectively. The space between the set of three front stop surfaces 11s-1 and the set of three rear stop surfaces 11s-2 is the same as the space between the set of three front stop surfaces 12s-1 and the set of three rear stop surfaces 12s-2.

20 When the zoom lens 71 is in the retracted state, each front stop surface 12s-1 comes very close to the associated front stop surface 11s-1 while each rear stop surface 12s-2 comes very close to the associated rear stop surface 11s-2 so that the first external barrel 12 does  
25 not further move rearward beyond the position thereof

shown in Figures 90 and 95. In the lens barrel retracting operation of the zoom lens 71, the first external barrel 12 stops moving rearward immediately before each front stop surface 12s-1 and each rear stop surface 12s-2 comes 5 into contact with the associated front stop surface 11s-1 and the associated rear stop surface 11s-2, respectively, because the first external barrel 12 stops being driven in the optical axis direction by the cam ring 11 via the set of three cam followers 31 at the time when the set 10 of three cam followers 31 respectively enter the rear end opening sections 11b-Y of the set of three outer cam grooves 11b due to a wide circumferential width of each rear end opening section 11b-Y. The space between the set of three front stop surfaces 11s-1 and the set of three 15 front stop surfaces 12s-1 in the retracted state of the zoom lens 71 is predetermined at approximately 0.1 mm. Likewise, the space between the set of three rear stop surfaces 11s-2 and the set of three rear stop surfaces 12s-2 in the retracted state of the zoom lens 71 is also 20 predetermined at approximately 0.1 mm. However, in an alternative embodiment, the first external barrel 12 can be allowed to retract by inertia so that the front stop surfaces 11s-1 and 12s-1 and the rear stop surfaces 11s-2 and 12s-2 contact each other, respectively.

25 The first external barrel 12 is provided on an inner

peripheral surface thereof with an inner flange 12c which projects radially inwards. The set of three front stop surfaces 12s-1 are positioned in front of the inner flange 12c in the optical axis direction. The inner flange 12c of the first external barrel 12 is provided with a set of three radial recesses 12d through which the set of three front projecting portions 11f can pass the inner flange 12c in the optical axis direction, respectively. When the set of three front stop surfaces 11s-1 approach the set of three front stop surfaces 12s-1, the set of three front projecting portions 11f passes the inner flange 12c through the set of three radial recesses 12d.

Although each of the cam ring 11 and the first external barrel 12 is provided, at front and rear portions thereof in the optical axis direction, with a set of front stop surfaces (11s-1 or 12s-1) and a set of rear stop surfaces (11s-2 or 12s-2) in the present embodiment of the zoom lens, each of the cam ring 11 and the first external barrel 12 can be provided with only one of the set of front stop surfaces or the set of rear stop surfaces to determine the rear limit for the axial movement of the first external barrel 12 with respect to the cam ring 11. Conversely, each of the cam ring 11 and the first external barrel 12 can be provided with one or more additional sets 25 of stop surfaces. For instance, in addition to the front

stop surfaces 11s-1 and 12s-1 and the rear stop surfaces 11s-2 and 12s-2, three front end surfaces 11h each of which are formed between two adjacent front projecting portions 11f can be made to be capable of coming into contact with 5 a rear surface 12h of the inner flange 12c to determine the rear limit for the axial movement of the first external barrel 12 with respect to the cam ring 11. Note that the front projecting portions 11f do not contact with the rear surface 12h, in the illustrated embodiment.

10 In each of the three outer cam grooves 11b, the entire section thereof except for the front end opening section 11b-X serving as a lens-barrel assembling/disassembling section serves as a lens-barrel operating section consisting of a zooming section and a 15 lens-barrel retracting section. Namely, a specific section of each of the three outer cam grooves 11b which extends from the position of the associated cam follower 31 in the outer cam groove 11b shown in Figures 90 and 95 (i.e., the rear end opening section 11b-Y), where the 20 zoom lens 71 is in the retracted state, to that shown in Figures 93 and 99, where the zoom lens 71 is set at the telephoto extremity serves as a lens-barrel operating section consisting of a zooming section and a lens-barrel retracting section. In the present embodiment of the 25 zoom lens, the rear end opening section 11b-Y of each outer

cam groove 11b is formed as an opening which is open at the rear of the cam ring 11. This structure makes it unnecessary to form any rear end wall having a certain thickness on a portion of the cam ring 11 behind each rear 5 end opening section 11b-Y, thus reducing the length of the cam ring 11 in the optical axis direction. In a conventional cam ring having cam grooves thereon, at least the terminal end of an operating section of each cam groove (one end of each cam groove if the other end is an open 10 end for the insertion of the associated cam groove in the cam groove) has to be formed as a closed end which requires the cam ring to have a end wall having a certain thickness to close the terminal end of the operating section of each cam groove. This kind of end wall does not have to be 15 formed on the cam ring 11 of the present embodiment of the zoom lens, which is advantageous to downsize the cam ring 11.

The reason why the rear end of each outer cam groove 11b is successfully formed as an open end such as the rear 20 end opening section 11b-Y is that the rear limit for the axial movement of the first external barrel 12 with respect to the cam ring 11 is determined by the front stop surfaces (11s-1 and 12s-1) and the rear stop surfaces (11s-2 and 12s-2) which are provided independent of the 25 set of three outer cam grooves 11b and the set of three

cam followers 31. Providing the cam ring 11 and the first external barrel 12 with such stop surfaces as the front and rear stop surfaces (11s-1, 12s-1, 11s-2 and 12s-2) that operate independently of the set of three outer cam 5 grooves 11b and the set of three cam followers 31, eliminates a possibility of each cam follower 31 becoming incapable of being re-engaged in the associated outer cam groove 11b through the rear end opening section 11b-Y thereof if each cam follower 31 should be disengaged 10 therefrom.

When the set of three cam followers 31 are respectively positioned in the rear end opening sections 11b-Y of the set of three outer cam grooves 11b, the optical elements of the zoom lens 71 are not required to 15 have a high degree of positioning accuracy because the zoom lens 71 is in the retracted state as shown in Figure 10. Due to this reason, there is no substantial problem even if each rear end opening section 11b-Y has a wide circumferential width so that each cam follower 31 is 20 loosely engaged in the associated rear end opening section 11b-Y. Conversely, the lens-barrel retracting section of the lens-barrel operating section of each outer cam groove 11b is successfully formed as an open end such as the rear end opening section 11b-Y because the lens-barrel 25 retracting section of the lens-barrel operating section

of each outer cam groove 11b, in which the associated cam follower 31 is allowed to be loosely engaged, is formed at the terminal end of the outer cam groove 11b and further because the entire cam contour of each outer cam groove 5 11b is determined so that the terminal end thereof is positioned at the rearmost position of the outer cam groove 11b in the optical axis direction.

To make each cam follower 31 move from the rear end opening section 11b-Y, in which the cam follower 31 is 10 loosely engaged, to the inclined lead section 11b-L of the associated outer cam groove 11b with reliability, the cam ring 11 is provided at different circumferential positions with a set of three beveled lead surfaces 11t while the first external barrel 12 is provided at 15 different circumferential positions with a set of three beveled lead surfaces 12t. The set of three beveled lead surfaces 11t are formed to adjoin the set of three front stop surfaces 11s-1 on the set of three front projecting portions 11f so that the set of three beveled lead surfaces 20 11t and the set of three front stop surfaces 11s-1 become a set of three continuous surfaces, respectively. The first external barrel 12 is provided at different circumferential positions with a set of three rear end protrusions 12f each having a substantially isosceles 25 triangle shape. The set of three engaging protrusions

12a are formed on the set of three rear end protrusions 12f, respectively. One of the two equal sides of each rear end protrusion 12f is formed as one of the three beveled lead surfaces 12t. As shown in Figures 95 through 5 100, each beveled lead surface 11t and each beveled lead surface 12t extend parallel to the inclined lead section 11b-L.

In the state shown in Figures 90 and 95 in which the zoom lens 71 is in the retracted state, an edge ED1 of 10 each of the three inner flanges 12c is positioned to be opposed to the adjacent beveled lead surface 11t in a circumferential direction, and also an edge ED2 of each of the three external protuberances 11g is positioned to be opposed to the adjacent beveled lead surface 12t in 15 a circumferential direction. In addition, in the same state shown in Figures 90 and 95, the edge ED1 of each inner flange 12c is slightly apart from the adjacent beveled lead surface 11t while the edge ED2 of each external protuberance 11g is slightly apart from the 20 adjacent beveled lead surface 12t. In this state shown in Figures 90 and 95, a rotation of the cam ring 11 in the lens barrel advancing direction (upwards as viewed in Figures 91 and 96) causes each beveled lead surface 11t to come into contact with the edge ED1 of the adjacent 25 inner flange 12c, and at the same time causes each beveled

lead surface 12t to come into contact with the edge ED2 of the associated external protuberance 11g as shown in Figures 91 and 96. Accordingly, at an initial stage of rotation of the cam ring 11 from the state shown in Figure 5 95, in which the three edges ED1 and the three edges ED2 are respectively apart from the three beveled lead surfaces 11t and the three beveled lead surfaces 12t, to the state shown in Figure 96, in which the three edges ED1 and the three edges ED2 are respectively in contact 10 with the three beveled lead surfaces 11t and the three beveled lead surfaces 12t, each cam follower 31 moves solely within the associated rear end opening section 11b-Y in a circumferential direction of the cam ring 11, so that the first external barrel 12 is not moved in the 15 optical axis direction with respect to the cam ring 11 by rotation of the cam ring 11.

In the state shown in Figures 91 and 96, in which the three edges ED1 and the three edges ED2 are respectively in contact with the three beveled lead surfaces 11t and the three beveled lead surfaces 12t, each 20 cam follower 31 is positioned at the insertion end of the inclined lead section 11b-L of the associated outer cam groove 11b. A further rotation of the cam ring 11 causes each edge ED1 to slide on the associated beveled lead 25 surface 11t and at the same time causes each edge ED2 to

slide on the associated beveled lead surface 12t so that the first external barrel 12 is pushed forward with respect to the cam ring 11 by the three beveled lead surfaces 11t in accordance with the sliding movements of 5 the three edges ED1 and the three edges ED2 on the three beveled lead surfaces 11t and the three beveled lead surfaces 12t, respectively. Since each beveled lead surface 11t and each beveled lead surface 12t extend parallel to the inclined lead section 11b-L, the force 10 acting on the first external barrel 12 by the rotation of the cam ring 11 via the three beveled lead surfaces 11t causes each cam follower 31 to move into the inclined lead section 11b-L of the associated outer cam groove 11b from the rear end opening section 11b-Y thereof. After 15 each cam follower 31 completely enters the inclined lead section 11b-L of the associated outer cam groove 11b as shown in Figure 97, each beveled lead surface 11t and each beveled lead surface 12t are disengaged from the associated edge ED1 and the associated edge ED2, 20 respectively, and accordingly, the first external barrel 12 is guided linearly in the optical axis direction due only to the engagement of the set of three cam followers 31 with the set of three outer cam grooves 11b, respectively.

25 Accordingly, in the lens barrel advancing operation

of the zoom lens 71 which commences from the retracted state shown in Figure 10, providing the cam ring 11 and the first external barrel 12 with the three beveled lead surfaces 11t and the three beveled lead surfaces 12t, 5 whose functions are similar to those of the three inclined lead section 11b-L, and further providing the first external barrel 12 with the three edge ED2 and the three ED1, whose functions are similar to those of the three cam followers 31, respectively, make it possible to have 10 each cam follower 31 enter the inclined lead section 11b-L of the associated outer cam groove 11b properly to move therein toward the associated curved section 11b-Z even from a state as shown in Figure 95 where each cam follower 31 is loosely engaged in the associated rear end opening 15 section 11b-Y. This prevents the zoom lens 71 from malfunctioning.

Although each of the cam ring 11 and the first external barrel 12 is provided with a set of three beveled lead surfaces (11t or 12t) in the present embodiment of 20 the zoom lens, only one of the cam ring 11 and the first external barrel 12 can be provided with a set of three beveled lead surfaces (11t or 12t), or each of the cam ring 11 and the first external barrel 12 can be provided with more than one set of three beveled lead surfaces.

25           Figure 101 shows another embodiment of the structure

shown in Figure 95, in which the zoom lens 71 is in the retracted state. Elements shown in Figure 101 which are similar to those shown in Figure 95 are designated by the same reference numerals each of which the mark (') is  
5 appended to.

Each outer cam groove 11b' is provided at the rear end of each inclined lead section 11b-L' with a rear end opening 11b-K instead of the rear end opening section 11b-Y of the cam ring 11 shown in Figure 95. Unlike each 10 rear end opening section 11b-Y, each rear end opening 11b-K is formed as a simple end opening of the associated outer cam groove 11b. Performing the lens barrel retracting operation in a state where the zoom lens is set at the wide-angle extremity causes each cam follower 15 31' to move rearward (rightward as viewed in Figure 101) in the associated inclined lead section 11b-L', and subsequently causes each cam follower 31' to come out of the associated outer cam groove 11b' through the rear end opening 11b-K thereof upon the zoom lens reaching the 20 retracted position thereof. If each cam follower 31' comes out of the associated outer cam groove 11b' through the rear end opening 11b-K thereof, the first external barrel 12' stops being driven by the cam ring 11' via the set of three cam followers 31' and therefore stops moving 25 rearward. At this time, the first external barrel 12'

is prevented from further moving rearward because each front stop surface 12s-1' and each rear stop surface 12s-2' are positioned very close to the associated front stop surface 11s-1' and the associated rear stop surface 5 11s-2', respectively. Therefore, the first external barrel 12' is prevented from moving rearward overly even if each cam follower 31' comes out of the associated outer cam groove 11b' through the rear end opening 11b-K thereof. In this embodiment shown in Figure 101, similar to the 10 embodiment shown in Figure 95, the space between the set of three front stop surfaces 11s-1' and the set of three front stop surfaces 12s-1' in the retracted state of the zoom lens is desirably at approximately 0.1 mm. Likewise, the space between the set of three rear stop surfaces 15 11s-2' and the set of three rear stop surfaces 12s-2' in the retracted state of the zoom lens is desirably at approximately 0.1 mm. However, in an alternative embodiment, the first external barrel 12' can be allowed to retract by inertia so that the front stop surfaces 20 11s-1' and 12s-1' and the rear stop surfaces 11s-2' and 12s-2' contact each other, respectively.

According to the structure shown in Figure 101 in which each cam follower 31' comes out of the associated outer cam groove 11b' in the retracted state of the zoom 25 lens 71, it is possible to further downsize the cam ring

11' because each outer cam groove 11b' does not have to be provided with any accommodation section, which corresponds to each rear end opening section 11b-Y of the cam ring 11, for accommodating the associated cam follower 5 therein when the zoom lens is in the retracted position.

In the retracted state shown in Figure 101, the edge ED1' of each of the three inner flanges 12c' is in contact with the beveled lead surface 11t' of the associated front projecting portions 11f' while the edge ED2' of each of 10 the three external protuberances 11g' is in contact with the beveled lead surface 12t' of the associated rear projecting portions 12f'. Each beveled lead surface 11t' and each beveled lead surface 12t' extend parallel to the inclined lead section 11b-L'. Due to this structure, 15 rotating the cam ring 11' in the retracted state shown in Figure 101 causes the first external barrel 12' to be pushed forward with respect to the cam ring 11', and subsequently causes each cam follower 31' which is currently positioned outside the associated outer cam 20 groove 11b' to move into the inclined lead section 11b-L' of the associated outer cam groove 11b' from the rear end opening 11b-K thereof. Thereafter, a further rotation of the cam ring 11' in the lens barrel advancing direction causes each cam follower 31' to move into the associated 25 curved section 11b-Z' in the associated outer cam groove

11b'. Thereafter, each cam follower 31' moves in the associated outer cam groove 11b' to perform a zooming operation in accordance with rotation of the cam ring 11'. Moving each cam follower 31' to the front end opening 5 sections 11b-X of the associated outer cam groove 11b makes it possible to remove the first external barrel 12' from the cam ring 11'.

As can be understood from the foregoing, also in the embodiment shown in Figure 101, the rear limit for the 10 axial movement of the first external barrel 12' with respect to the cam ring 11' can be surely determined, while each cam follower 31' can properly enter the inclined lead section 11b-L' of the associated outer cam groove 11b' even though each cam follower 31' comes out of the 15 associated outer cam groove 11b' through the rear end opening 11b-K thereof when the zoom lens is retracted into the camera body.

The structure of the zoom lens 71 which accommodates the zoom lens 71 in the camera body 72 as shown in Figure 20 9 upon a main switch (not shown) of the digital camera 70 being turned OFF, which incorporates the structure retracting the second lens frame 6 (the second lens group LG2) to the radially retracted position, will be hereinafter discussed in detail. In the following 25 descriptions the terms "vertical direction" and

"horizontal direction" mean the vertical direction and the horizontal direction as viewed from front or rear of the digital camera 70 such as the vertical direction of Figure 110 and the horizontal direction of Figure 111,  
5 respectively. In addition, the term "forward/backward direction" corresponds to the optical axis direction (i.e., a direction parallel to the photographing optical axis Z1).

The second lens group LG2 is supported by the second  
10 lens group moving frame 8 via peripheral elements shown in Figures 102. The second lens frame 6 is provided with a cylindrical lens holder portion 6a, a pivoted cylindrical portion 6b, a swing arm portion 6c and an engaging protrusion 6e. The cylindrical lens holder portion 6a directly holds and supports the second lens group L2. The swing arm portion 6c extends in a radial direction of the cylindrical lens holder portion 6a to connect the cylindrical lens holder portion 6a to the pivoted cylindrical portion 6b. The engaging protrusion  
15 6e is formed on the cylindrical lens holder portion 6a to extend in a direction away from the swing arm portion 6c. The pivoted cylindrical portion 6b is provided with a through hole 6d extending in a direction parallel to the optical axis of the second lens group LG2. The  
20 pivoted cylindrical portion 6b is provided at front and  
25

rear ends thereof, on front and rear sides of a portion of the pivoted cylindrical portion 6b which is connected to the swing arm portion 6c, with a front spring support portion 6f and a rear spring support portion 6g,  
5 respectively. The front spring support portion 6f is provided, on an outer peripheral surface thereof in the vicinity of the front end of the front spring support portion 6f, with a front spring hold projection 6h. The rear spring support portion 6g is provided, on an outer peripheral surface thereof in the vicinity of the rear end of the rear spring support portion 6g, with a rear spring hold projection 6i. The pivoted cylindrical portion 6b is provided on an outer peripheral surface thereof with a position control arm 6j extending in a direction away from the swing arm portion 6c. The position control arm 6j is provided with a first spring engaging hole 6k, and the swing arm portion 6c is provided with a second spring engaging hole 6p (see Figures 118 through 120).  
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15

20 The second lens frame 6 is provided with a rear projecting portion 6m which projects rearward in the optical axis direction from the swing arm portion 6c. The rear projecting portion 6m is provided at the rear end thereof with a contacting surface 6n which lies in a plane  
25 orthogonal to the optical axis of the second lens group

LG2, i.e., to the photographing optical axis Z1. Although a light shield ring 9 is fixed as shown in Figures 104, 105, 128 and 129, the contacting surface 6n is positioned behind the second lens group light shield ring 5 in the optical axis direction. Namely, the contacting surface 6n is positioned behind the rearmost position of the second lens group LG2 in the optical axis direction.

The front second lens frame support plate 36 is a vertically-elongated narrow plate having a narrow width 10 in horizontal direction. The front second lens frame support plate 36 is provided with a first vertically-elongated hole 36a, a pivot hole 36b, a cam-bar insertable hole 36c, a screw insertion hole 36d, a horizontally-elongated hole 36e and a second vertically-elongated hole 15 36f, in this order from top to bottom of the front second lens frame support plate 36. All of these holes 36a through 36f are through holes which penetrate the front second lens frame support plate 36 in the optical axis direction. The front second lens frame support plate 36 20 is provided on an outer edge thereof in the vicinity of the first vertically-elongated hole 36a with a spring engaging recess 36g.

Similar to the front second lens frame support plate 36, the rear second lens frame support plate 37 is also 25 a vertically-elongated narrow plate having a narrow width

in horizontal direction. The rear second lens frame support plate 37 is provided with a first vertically-elongated hole 37a, a pivot hole 37b, a cam-bar insertable hole 37c, a screw hole 37d, a horizontally-elongated hole 37e and a second vertically-elongated hole 37f, in this order from top to bottom of the rear second lens frame support plate 37. All of these holes 37a through 37f are through holes which penetrate through the rear second lens frame support plate 37 in the optical axis direction. The 10 rear second lens frame support plate 37 is provided on an inner edge of the cam-bar insertable hole 37c with a guide key insertable recess 37g. The through holes 36a through 36f of the front second lens frame support plate 36 and the through holes 37a through 37f of the rear second 15 lens frame support plate 37 are aligned in the optical axis direction, respectively.

The set screw 66 is provided with a threaded shaft portion 66a and a head portion fixed to an end of the threaded shaft portion 66. The head portion is provided 20 with a cross-slot 66b into which the tip of a Phillips screwdriver (not shown) serving as an adjusting tool can be inserted. The screw insertion hole 36d of the front second lens frame support plate 36 has a diameter by which the threaded shaft portion 66a of the set screw 66 is 25 insertable. The threaded shaft portion 66a of the set

screw 66 can be screwed through the screw hole 37d of the rear second lens frame support plate 37 to fix the front second lens frame support plate 36 and the rear second lens frame support plate 37 to the second lens group moving  
5 frame 8.

The zoom lens 71 is provided between the front second lens frame support plate 36 and the rear second lens frame support plate 37 with a first eccentric shaft 34X which extends in the optical axis direction. The first 10 eccentric shaft 34X is provided with a large diameter portion 34X-a, and is provided at front and rear ends of the large diameter portion 34X-a with a front eccentric pin 34X-b and a rear eccentric pin 34X-c which project forward and rearward in the optical axis direction, 15 respectively. The front eccentric pin 34X-b and the rear eccentric pin 34X-c have the common axis eccentric to the axis of the large diameter portion 34X-a. The front eccentric pin 34X-b is provided at the front end thereof with a recess 34X-d into which the tip of a flatblade 20 screwdriver (not shown) serving as an adjusting tool can be inserted.

The zoom lens 71 is provided between the front second lens frame support plate 36 and the rear second lens frame support plate 37 with a second eccentric shaft 34Y which 25 extends in the optical axis direction. The structure of

the second eccentric shaft 34Y is the same as the structure of the first eccentric shaft 34X. Namely, the second eccentric shaft 34Y is provided with a large diameter portion 34Y-a, and is provided at front and rear ends of 5 the large diameter portion 34Y-a with a front eccentric pin 34Y-b and a rear eccentric pin 34Y-c which projects forward and rearward in the optical axis direction, respectively. The front eccentric pin 34Y-b and the rear eccentric pin 34Y-c have the common axis eccentric to the 10 axis of the large diameter portion 34Y-a. The front eccentric pin 34Y-b is provided at the front end thereof with a recess 34Y-d into which the tip of a flatblade screwdriver (not shown) serving as an adjusting tool can be inserted.

15       The bore diameter of a rear end portion of the through hole 6d that penetrates the second lens frame 6 is increased to form a spring-accommodation large diameter hole 6Z (see Figure 126) so that the compression coil spring 38 is accommodated in the spring-accommodation large diameter hole 6Z. The front torsion 20 coil spring 39 and a rear torsion coil spring 40 are fitted on the front spring support portion 6f and the rear spring support portion 6g, respectively. The front torsion coil spring 39 is provided with a front spring end 39a and a 25 rear spring end 39b, and the rear torsion coil spring 40

is provided with a front stationary spring end 40a and a rear movable spring end 40b.

The pivot shaft 33 is fitted in the through hole 6d from the rear end thereof so that the pivoted cylindrical portion 6b of the second lens frame 6 can freely rotate on the pivot shaft 33 with no play in radial directions. The diameters of front and rear ends of the pivot shaft 33 correspond to the pivot hole 36b of the front second lens frame support plate 36 and the pivot hole 37b of the rear second lens frame support plate 37 so that the front and rear ends of the pivot shaft 33 are fitted in the pivot hole 36b and the pivot hole 37b to be supported by the front second lens frame support plate 36 and the rear second lens frame support plate 37, respectively. In a state where the pivot shaft 33 is fitted in the through hole 6d, the axis of the pivot shaft 33 extends parallel to the optical axis of the second lens group LG2. As shown in Figure 113, the pivot shaft 33 is provided in the vicinity of the rear end thereof with a flange 33a which is inserted in the spring-accommodation large diameter hole 6z to contact with the rear end of the compression coil spring 38 that is accommodated in the spring-accommodation large diameter hole 6z.

As clearly shown in Figures 106 and 107, the second lens group moving frame 8 is an annular member having a

through internal space 8n which penetrates the second lens group moving frame 8 in the optical axis direction. The second lens group moving frame 8 is provided, on an inner peripheral surface thereof at a substantially center 5 thereof in the optical axis direction, with a central inner flange 8s. The inner edge of the central inner flange 8s forms a vertically-elongated opening 8t in which the second lens frame 6 is swingable. The shutter unit 76 is fixed to a front surface of the central inner flange 10 8s. The second lens group moving frame 8 is provided on an inner peripheral surface thereof behind the central inner flange 8s in the optical axis direction with a first radial recess 8q (see Figures 111 and 112) which is recessed radially outwards (upwards as viewed in Figure 15 111) to correspond to the shape of an outer peripheral surface of the cylindrical lens holder portion 6a of the second lens frame 6 so that the cylindrical lens holder portion 6a can partly enter the radial recess 8q. The second lens group moving frame 8 is further provided on 20 an inner peripheral surface thereof behind the central inner flange 8s with a second radial recess 8r (see Figures 111 and 112) which is recessed radially outwards to correspond to the shape of an outer edge of the engaging protrusion 6e of the second lens frame 6 so that the 25 engaging protrusion 6e can partly enter the second radial

recess 8r.

As shown in Figures 106 and 107, the second lens group moving frame 8 is provided on a front end surface thereof (specifically, a right portion of the front end 5 surface of the second lens group moving frame 8, on the right hand side of the vertically-elongated opening 8t, as viewed from front of the second lens group moving frame 8) with a vertically-elongated front fixing surface 8c to which the front second lens frame support plate 36 is 10 fixed. The front fixing surface 8c is hatched in Figures 106 and 107 for the purpose of illustration. The front fixing surface 8c does not overlap the vertically-elongated opening 8t in the optical axis direction, and lies in a plane orthogonal to the lens barrel axis Z0 (the 15 photographing optical axis Z1, the optical axis of the second lens group LG2). The front fixing surface 8c is positioned in front of the shutter unit 76 in the optical axis direction. The front fixing surface 8c is formed to be exposed to the front of the second lens group moving 20 frame 8. The second lens group moving frame 8 is provided at the front end thereof with a set of three extensions 8d extending forward in the optical axis direction. The set of three extensions 8d are formed as extensions of the second lens group moving frame 8 which extend forward 25 from the front end of the second lens group moving frame

8. The set of three front cam followers 8b-1 are formed on outer peripheral surfaces of the set of three extensions 8d, respectively. The second lens group moving frame 8 is provided on a rear end surface thereof  
5 (specifically, a left portion of the rear end surface of the second lens group moving frame 8, on the left hand side of the vertically-elongated opening 8t, as viewed from rear of the second lens group moving frame 8) with a vertically-elongated rear fixing surface 8e to which  
10 the rear second lens frame support plate 37 is fixed. The rear fixing surface 8e is positioned on the opposite side of the central inner flange 8s from the front fixing surface 8c in the optical axis direction to be parallel to the front fixing surface 8c. The rear fixing surface  
15 8e is formed as a part of the rear end surface of the second lens group moving frame 8; namely, the rear fixing surface 8e is flush with the rear end surface of the second lens group moving frame 8.

The second lens group moving frame 8 is provided with  
20 a first eccentric shaft support hole 8f, a pivoted cylindrical portion receiving hole 8g, a screw insertion hole 8h and a second eccentric shaft support hole 8i, in this order from top to bottom of the second lens group moving frame 8. All of these holes 8f, 8g, 8h and 8i are  
25 through holes which penetrate the second lens group moving

frame 8 in the optical axis direction between the front fixing surface 8c and the rear fixing surface 8e. The through holes 8f, 8h and 8i of the second lens group moving frame 8 are aligned with the through holes 36a, 36d and 5 36e of the front second lens frame support plate 36, respectively, and also aligned with the through holes 37a, 37d and 37e of the rear second lens frame support plate 37 in the optical axis direction, respectively. The second lens group moving frame 8 is provided on an inner 10 peripheral surface thereon in the pivoted cylindrical portion receiving hole 8g with a key way 8p extending in the optical axis direction. The key way 8p penetrates the second lens group moving frame 8 in the optical axis direction between the front fixing surface 8c and the rear 15 fixing surface 8e. The diameter of the first eccentric shaft support hole 8f is determined so that the large diameter portion 34X-a is rotatably fitted in the first eccentric shaft support hole 8f, and the diameter of the second eccentric shaft support hole 8i is determined so 20 that the large diameter portion 34Y-a is rotatably fitted in the second eccentric shaft support hole 8i (see Figure 113). On the other hand, the diameter of the screw insertion hole 8h is determined so that the threaded shaft portion 66a is inserted in the screw insertion hole 8h 25 with a substantial gap between the threaded shaft portion

66a and an inner peripheral surface of the screw insertion hole 8h (see Figure 113). The second lens group moving frame 8 is provided on the front fixing surface 8c and the rear fixing surface 8e with a front boss 8j and a rear  
5 boss 8k which project forward and rearward in the optical axis direction, respectively. The front boss 8j and the rear boss 8k have a common axis extending in the optical axis direction. The second lens group moving frame 8 is provided below the vertically-elongated opening 8t with  
10 a through hole 8m which penetrates through the central inner flange 8s in the optical axis direction so that the rotation limit shaft 35 can be inserted into the vertically-elongated opening 8t.

The rotation limit shaft 35 is provided with a large  
15 diameter portion 35a, and is provided at a rear end thereof with an eccentric pin 35b which projects rearward in the optical axis direction. The axis of the eccentric pin 35b is eccentric to the axis of the large diameter portion 35. The rotation limit shaft 35 is provided at a front  
20 end thereof with a recess 35c into which the tip of a flatblade screwdriver (not shown) serving as an adjusting tool can be inserted.

Figures 108 through 112 show a state where the above described assemble parts shown in Figures 102 through 107  
25 are put together, viewed from different angles. A manner

of putting the assembled parts together will be discussed hereinafter.

First, the front torsion coil spring 39 and the rear torsion coil spring 40 are fixed to the second lens frame 5 6. At this time, a coil portion of the front torsion coil spring 39 is fitted on the front spring support portion 6f of the pivoted cylindrical portion 6b with the rear spring end 39b being engaged with a portion of the second lens frame 6 between the pivoted cylindrical portion 6b 10 and the swing arm portion 6c (see Figure 104). The front spring end 39a of the front torsion coil spring 39 is not engaged with any part of the second lens frame 6. A coil portion of the rear torsion coil spring 40 is fitted on the rear spring support portion 6g of the pivoted 15 cylindrical portion 6b with the front stationary spring end 40a and the rear movable spring end 40b being inserted into the second spring engaging hole 6p of the swing arm portion 6c and the first spring engaging hole 6k of the position control arm 6j, respectively. The front 20 stationary spring end 40a is fixed to the second spring engaging hole 6p while the rear movable spring end 40b is allowed to move in the first spring engaging hole 6k in a range "NR1" shown in Figure 120. In a free state, the rear torsion coil spring 40 is supported by the second 25 lens frame 6 thereon with the front stationary spring end

40a and the rear movable spring end 40b being slightly pressed to move in opposite directions approaching each other so that the rear movable spring end 40b is in pressing contact with an inner wall surface of the 5 position control arm 6j in the first spring engaging hole 6k (see Figure 120). The front torsion coil spring 39 is prevented from coming off the front spring support portion 6f from the front end thereof in the optical axis direction by the front spring hold projection 6h, while 10 the rear torsion coil spring 40 is prevented from coming off the rear spring support portion 6g from the rear end thereof in the optical axis direction by the rear spring hold projection 6i.

Aside from the installation of the front torsion 15 coil spring 39 and the rear torsion coil spring 40, the pivot shaft 33 is inserted into the through hole 6d after the compression coil spring 38 is inserted into the spring-accommodation large diameter hole 6z that is formed in the rear end portion of the rear spring support 20 portion 6g. At this time, the flange 33a of the pivot shaft 33 enters the rear spring support portion 6g to contact with the rear end of the compression coil spring 38. The axial length of the pivot shaft 33 is greater than the axial length of the pivoted cylindrical portion 25 6b so that the opposite ends of the pivot shaft 33 project

from the front and rear ends of the pivoted cylindrical portion 6b, respectively.

Concurrent with the above described installation operations to the pivoted cylindrical portion 6b, the 5 first eccentric shaft 34X and the second eccentric shaft 34Y are inserted into the first eccentric shaft support hole 8f and the second eccentric shaft support hole 8i, respectively. As shown in Figure 113, the diameter of a front end portion (left end portion as viewed in Figure 10 113) of the large diameter portion 34X-a of the first eccentric shaft 34X is greater than the diameter of the remaining portion of the large diameter portion 34X-a, and the inner diameter of a corresponding front end portion (left end portion as viewed in Figure 113) of the 15 first eccentric shaft support hole 8f is greater than the inner diameter of the remaining portion of the first eccentric shaft support hole 8f. Likewise, the diameter of a front end portion (left end portion as viewed in Figure 113) of the large diameter portion 34Y-a of the second eccentric shaft 34Y is greater than the diameter 20 of the remaining portion of the large diameter portion 34Y-a, and the inner diameter of a corresponding front end portion (left end portion as viewed in Figure 113) of the second eccentric shaft support hole 8i is greater 25 than the inner diameter of the remaining portion of the

second eccentric shaft support hole 8i. Therefore, when inserted into the first eccentric shaft support hole 8f from the front end thereof (the left end as viewed in Figure 113), the first eccentric shaft 34X is prevented 5 from being further inserted into the first eccentric shaft support hole 8f upon the stepped portion between the large diameter portion 34X-a and the remaining portion of the first eccentric shaft 34X contacting with the bottom of the large-diameter front end portion of the first 10 eccentric shaft support hole 8f as shown in Figure 113. Likewise, when inserted into the second eccentric shaft support hole 8i from the front end thereof (the left end as viewed in Figure 113), the second eccentric shaft 34Y is prevented from being further inserted into the second 15 eccentric shaft support hole 8i upon the stepped portion between the large diameter portion 34Y-a and the remaining portion of the first eccentric shaft 34Y contacting with the bottom of the large-diameter front end portion of the second eccentric shaft support hole 8i as shown in Figure 20 113. In this state, the front eccentric pin 34X-b and the front eccentric pin 34Y-b project forward in the optical axis direction from the front fixing surface 8c while the rear eccentric pin 34X-c and the eccentric pin 34Y-c project rearward in the optical axis direction from 25 the rear fixing surface 8e.

Subsequently, the front second lens frame support plate 36 and the rear second lens frame support plate 37 are fixed to the front fixing surface 8c and the rear fixing surface 8e, respectively, while the front end of 5 the pivot shaft 33, which projects from the front end of the front spring support portion 6f of the pivoted cylindrical portion 6b, is fitted into the pivot hole 36b of the front second lens frame support plate 36 and at the same time the rear end of the pivot shaft 33 is fitted 10 into the pivot hole 37b of the rear second lens frame support plate 37. At this time, the front eccentric pin 34X-b, the front eccentric pin 34Y-b and the front boss 8j which project forward from the front fixing surface 8c are inserted into the first vertically-elongated hole 15 36a, the horizontally-elongated hole 36e and the second vertically-elongated hole 36f, respectively, and also the rear eccentric pin 34X-c, the rear eccentric pin 34Y-c and the rear boss 8k which project rearward from the rear fixing surface 8e are inserted into the first vertically-elongated hole 37a, the horizontally-elongated hole 37e and the second vertically-elongated hole 37f, respectively. The front eccentric pin 34X-b 20 is movable and immovable in the first vertically-elongated hole 36a in the lengthwise direction and the widthwise direction thereof (vertically and horizontally 25

as viewed in Figure 110), respectively, the front eccentric pin 34Y-b is movable and immovable in the horizontally-elongated hole 36e in the lengthwise direction and the widthwise direction thereof 5 (horizontally and vertically as viewed in Figure 110), respectively, and the front boss 8j is movable and immovable in the second vertically-elongated hole 36f in the lengthwise direction and the widthwise direction thereof (vertically and horizontally as viewed in Figure 10 110), respectively. Likewise, the rear eccentric pin 34X-c is movable and immovable in the first vertically-elongated hole 37a in the lengthwise direction and the widthwise direction thereof 15 (vertically and horizontally as viewed in Figure 111), respectively, the rear eccentric pin 34Y-c is movable and immovable in the horizontally-elongated hole 37e in the lengthwise direction and the widthwise direction thereof (horizontally and vertically as viewed in Figure 111), 20 respectively, and the rear boss 8k is movable and immovable in the second vertically-elongated hole 37f in the lengthwise direction and the widthwise direction thereof (vertically and horizontally as viewed in Figure 111), respectively.

Lastly, the threaded shaft portion 66a of the set 25 screw 66 is inserted into the screw insertion hole 36d

and the screw insertion hole 8h, and is screwed through the screw hole 37d to fix the front second lens frame support plate 36 and the rear second lens frame support plate 37 to the second lens group moving frame 8. In this state, screwing down the set screw 66 with the set screw 66 being engaged in the screw hole 37d causes the front second lens frame support plate 36 and the rear second lens frame support plate 37 to be pressed against the front fixing surface 8c and the rear fixing surface 8e, respectively, so that the front second lens frame support plate 36 and the rear second lens frame support plate 37 are fixed to the second lens group moving frame 8 with a spacing therebetween which corresponds to the spacing between the front fixing surface 8c and the rear fixing surface 8e in the optical axis direction. As a result, the first eccentric shaft 34X and the second eccentric shaft 34Y are prevented from coming off the second lens group moving frame 8 by the front second lens frame support plate 36 and the rear second lens frame support plate 37.

The front end of the pivoted cylindrical portion 6b is pressed against the front second lens frame support plate 36 because the flange 33a of the pivot shaft 33 contacts with the rear second lens frame support plate 37 to be prevented from moving rearward beyond the rear second lens frame support plate 37 so that the pivot shaft 33 is biased

forward in the optical axis direction by the spring force of the compression coil spring 38 which is compressed in the spring-accommodation large diameter hole 6Z of the rear spring support portion 6g. This maintains the 5 position of the second lens frame 6 relative to the second lens group moving frame 8 in the optical axis direction. In a state where the rear second lens frame support plate 37 is fixed to the second lens group moving frame 8, the guide key insertable recess 37g communicates with the key 10 way 8p in the optical axis direction (see Figure 112).

After the front second lens frame support plate 36 is fixed to the second lens group moving frame 8, the front spring end 39a of the front torsion coil spring 39 is placed into the spring engaging recess 36g. The rear spring end 39b of the front torsion coil spring 39 has been engaged with a portion of the second lens frame 6 between the pivoted cylindrical portion 6b and the swing arm portion 6c as mentioned above. Placing the front spring end 39a into the spring engaging recess 36g causes 15 the front torsion coil spring 39 to be twisted, thus causing the second lens frame 6 to be biased to rotate about the pivot shaft 33 in a counterclockwise direction as viewed from front of the second lens frame 6 20 (counterclockwise as viewed in Figure 114).

25 Aside from the installation of the second lens frame

6 , the rotation limit shaft 35 is inserted into the through hole 8m of the second lens group moving frame 8 from the front end of the through hole 8m. An inner peripheral surface in the through hole 8m is formed to prevent the  
5 rotation limit shaft 35 from being further inserted into the through hole 8m from the position of the rotation limit shaft 35 shown in Figures and 108 and 109. In this state where the rotation limit shaft 35 is properly inserted into the through hole 8m, the eccentric pin 35b of the  
10 rotation limit shaft 35 projects rearward from the rear end of the through hole 8m as shown in Figure 109.

In a state where the second lens frame 6 is properly mounted to the second lens group moving frame 8 in the above described manner, the second lens frame 6 can swing  
15 about the pivot shaft 33. The pivoted cylindrical portion receiving hole 8g of the second lens group moving frame 8 is sufficiently large so that the pivoted cylindrical portion 6b and the swing arm portion 6c may not interfere with the inner edge in the pivoted  
20 cylindrical portion receiving hole 8g when the second lens frame 6 swings. Since the pivot shaft 33 extends parallel to the photographing optical axis Z1 and the optical axis of the second lens group LG2, the second lens group LG2 swings about the pivot shaft 33 while the optical axis  
25 thereof remaining parallel to the photographing optical

axis Z1 when the second lens frame 6 swings. One end of the range of rotation of the second lens frame 6 about the pivot shaft 33 is determined by the engagement of the tip of the engaging protrusion 6e with the eccentric pin 5 35b as shown in Figure 111. The front torsion coil spring 39 biases the second lens frame 6 to rotate in a direction to bring the tip of the engaging protrusion 6e into contact with the eccentric pin 35b.

Subsequently, the shutter unit 76 is fixed to the 10 second lens group moving frame 8 to obtain a sub-assembly shown in Figures 108 through 112. As can be seen in Figures 108 through 112, the shutter unit 76 is fixed to the front of the central inner flange 8s. In this state where the shutter unit 76 is fixed to the front of the 15 central inner flange 8s, the front fixing surface 8c is positioned in front of the shutter S and the adjustable diaphragm A in the shutter unit 76 in the optical axis direction. A front portion of the cylindrical lens holder portion 6a of the second lens frame 6 is positioned 20 in the vertically-elongated opening 8t, and is also positioned immediately behind the shutter unit 76 regardless of variation of the position of the second lens frame 6 relative to the second lens group moving frame 8 as can be see in Figures 111 and 112.

25 In a state where the second lens group moving frame

8 and the second linear guide ring 10 are coupled to each other, the flexible PWB 77 that extends from the shutter unit 76 is installed as shown in Figure 125. As described above, the wide linear guide key 10c-W of the second linear 5 guide ring 10 is engaged in the wide guide groove 8a-W. The flexible PWB 77, the wide guide groove 8a-W and the wide linear guide key 10c-W in a radial direction of the lens barrel axis Z0 are positioned in the same position in a circumferential direction of the zoom lens 71.

10 Namely, the flexible PWB 77, the wide guide groove 8a-W and the wide linear guide key 10c-W are aligned in a radial direction perpendicular to the optical axis direction. As shown in Figure 125, the flexible PWB 77 includes a first straight portion 77a, a loop-shaped turning portion 15 77b, a second straight portion 77c and a third straight portion 77d in this order from the side of the shutter unit 76. A bend of the flexible PWB 77 is formed between the second straight portion 77c and the third straight portion 77d in the vicinity of the front end of the wide 20 linear guide key 10c-W. From the side of the shutter unit 76 (the left side as viewed in Figure 125), firstly the first straight portion 77a extends rearward in the optical axis direction from the shutter unit 76, and subsequently the flexible PWB 77 bends radially outwards to extend 25 forward so that the loop-shaped turning portion 77b is

formed in the vicinity of the rear end of the second lens group moving frame 8 and so that the second straight portion 77c extends forward in the optical axis direction along an inner surface of the wide linear guide key 10c-W.

5 Subsequently, the flexible PWB bends radially outwards to extend rearward so that the third straight portion 77d extends rearward in the optical axis direction along an outer surface of the wide linear guide key 10c-W. Subsequently, the tip of the third straight portion 77d

10 (the tip of the flexible PWB) passes through the radial through hole 10d to extend rearward, is further passed through a hole 22q (see Figures 4 and 40) to extend through to the outer side of the stationary barrel 22, to be connected to the control circuit 140 via a main circuit board (not shown). The third straight portion 77d is

15 partly fixed to the outer surface of the wide linear guide key 10c-W by a fixing means such as a double-faced tape (not shown) so that the size of the loop-shaped turning portion 77b becomes variable in accordance with relative

20 axial movement between the second lens group moving frame 8 and the second linear guide ring 10.

The AF lens frame 51, which is positioned behind the second lens group moving frame 8, is made of an opaque material, and is provided with a forwardly-projecting

25 lens holder portion 51c, a first arm portion 51d and a

second arm portion 51e. The first arm portion 51d and the second arm portion 51e are positioned on radially opposite sides of the forwardly-projecting lens holder portion 51c. The forwardly-projecting lens holder portion 51c is positioned in front of the first arm portion 51d and the second arm portion 51e in the optical axis direction. The pair of guide holes 51a and 52a, in which the pair of AF guide shafts 52 and 53 are respectively fitted, are formed on the first arm portion 51d and the second arm portion 51e, respectively. The forwardly-projecting lens holder portion 51c is formed in a box shape (rectangular ring shape) including a substantially square-shaped front end surface 51c1 and four side surfaces 51c3, 51c4, 51c5 and 51c6. The front end surface 51c1 lies in a plane orthogonal to the photographing optical axis Z1. The four side surfaces 51c3, 51c4, 51c5 and 51c6 extend rearward in a direction substantially parallel to the photographing optical axis Z1, toward the CCD image sensor 60, from the four sides of the front end surface 51c1. The rear end of the forwardly-projecting lens holder portion 51c is formed as an open end which is open toward the low-pass filter LG4 the CCD image sensor 60. The forwardly-projecting lens holder portion 51c is provided on the front end surface 51c1 thereof with a circular opening 51c2 the center of which is coincident

with the photographing optical axis Z1. The third lens group LG3 is positioned inside the circular opening 51c2. The first arm portion 51d and the second arm portion 51e extend from the forwardly-projecting lens holder portion 51c radially in opposite directions away from each other. More specifically, the first arm portion 51d extends from a corner of the forwardly-projecting lens holder portion 51c between the two side surfaces 51c3 and 51c6 radially in a lower-rightward direction as viewed from front of the AF lens frame 51, while the second arm portion 51e extends from another corner of the forwardly-projecting lens holder portion 51c between the two side surfaces 51c4 and 51c5 radially in a upper-leftward direction as viewed from front of the AF lens frame 51 as shown in Figure 130.

As can be seen in Figures 128 and 129, the first arm portion 51d is fixed to the rear end of the corner of the forwardly-projecting lens holder portion 51c between the two side surfaces 51c3 and 51c6 while the second arm portion 51e is fixed to the rear end of the corner of the forwardly-projecting lens holder portion 51c between the two side surfaces 51c4 and 51c5.

As shown in Figure 9, radially outwards ends of the first arm portion 51d and the second arm portion 51e are positioned radially outside a cylindrical wall 22k of the stationary barrel 22. The pair of guide holes 51a and

52a are respectively formed on radially outer ends of the first arm portion 51d and the second arm portion 51e which are positioned outside the cylindrical wall 22k. Accordingly, the AF guide shaft 52, which is fitted in 5 the guide hole 51a and serves as a main guide shaft for guiding the AF lens frame 51 in the optical axis direction with a high positioning accuracy, is positioned outside the cylindrical wall 22k, while the AF guide shaft 53, which is loosely fitted in the guide hole 51b to serve 10 as an auxiliary guide shaft for secondarily guiding the AF lens frame 51 in the optical axis direction is also positioned outside the cylindrical wall 22k. As shown in Figure 9, the cylindrical wall 22k is provided on the outer peripheral surface thereof with two radial 15 projections 22t1 and 22t2 provided at different circumferential positions. A shaft-supporting hole 22v1 is formed on the rear surface of the radial projection 22t1. Similarly, a shaft-supporting hole 22v2 is formed on the rear surface of the radial projection 22t2. The 20 CCD holder 21 is provided on the front surface thereof with two shaft-supporting holes 21v1 and 21v2 which oppose the shaft-supporting holes 22v1 and 22v2 in the optical axis direction, respectively. The front end and the rear end of the AF guide shaft 52 are supported by (fixed to) 25 the shaft-supporting hole 22v1 and the shaft-supporting

hole 21v1, respectively. The front end and the rear end of the AF guide shaft 53 are supported by (fixed to) the shaft-supporting hole 22v2 and the shaft-supporting hole 21v2, respectively.

5       The cylindrical wall 22k is provided with two cutout portions 22m and 22n (see Figure 11) which are cut out along the AF guide shafts 52 and 53 to prevent the second arm portion 51e and the first arm portion 51d from interfering with the cylindrical wall 22k when the AF lens  
10 frame 51 moves in the optical axis direction. As shown in Figures 122 and 130, the pair of guide holes 51a and 52a are positioned on radially opposite sides of the photographing optical axis Z1, and accordingly, the pair of AF guide shafts 52 and 53 are positioned on radially  
15 opposite sides of the photographing optical axis Z1.

      The AF lens frame 51 can move rearward in the optical axis direction to a point (rear limit for the axial movement of the AF lens frame 51) at which the forwardly-projecting lens holder portion 51c comes into  
20 contact with the filter holder portion 21b (see Figure 10) formed on a front surface of the CCD holder 21. In other words, the CCD holder 21 includes a stop surface (front surface of the filter holder portion 21b) which determines rear limit for the axial movement of the AF  
25 lens frame 51. In a state where the forwardly-projecting

lens holder portion 51c is in contact with the filter holder portion 21b, the front end of the position-control cam bar 21a, which projects forward from the CCD holder 21, is positioned in front of the AF lens frame 5 51 in the optical axis direction (see Figures 121, 123 and 124). The cam-bar insertable hole 36c of the front second lens frame support plate 36 and the cam-bar insertable hole 37c of the rear second lens frame support plate 37 are positioned on an axis of the position-control 10 cam bar 21a. Namely, the cam-bar insertable hole 36c, the cam-bar insertable hole 37c and the position-control cam bar 21a are aligned in the optical axis direction.

As shown in Figures 103 and 104, the position-control cam bar 21a is provided at a front end thereof 15 with the aforementioned retracting cam surface 21c which is inclined with respect to the optical axis direction, and is further provided along an inner side edge of the position-control cam bar 21a with a removed-position holding surface 21d which extends rearward from the 20 retracting cam surface 21c in the optical axis direction. As can be seen in Figures 118 through 120 and 122, in which the position-control cam bar 21a is viewed from front thereof, the position-control cam bar 21a has a certain width in a substantially radial direction of the 25 photographing optical axis Z1. The retracting cam

surface 21c is formed as an inclined surface which is inclined forward in a direction from the radially inner side to the radially outer side of the position-control cam bar 21a (i.e., from a side closer to the photographing optical axis Z1 to a side farther from the photographing optical axis Z1), substantially along a widthwise direction of the retracting cam surface 21c. In other words, the retracting cam surface 21c is formed as an inclined surface which is inclined forward in a direction away from the photographing optical axis Z1. In Figures 118 through 120, the retracting cam surface 21c is hatched for the purpose of illustration. Moreover, the position-control cam bar 21a is formed so that an upper surface and a lower surface of the position-control cam bar 21a become a concave surface and a convex surface, respectively, to prevent the position-control cam bar 21a from interfering with the pivoted cylindrical portion 6b of the second lens frame 6. In other words, the position-control cam bar 21a is formed as a portion a cylinder centered about the pivot shaft 33 of the second lens group 6, and the retracting cam surface 21c is a lead surface which is formed on the periphery (edge surface) of this cylinder. . The position-control cam bar 21a is provided on a lower surface thereof with a guide key 21e which is elongated in the optical axis direction. The

guide key 21e extends from the rear end of the position-control cam bar 21a to an intermediate point thereon behind the front end of the position-control cam bar 21a. Therefore, no part of the guide key 21e is formed  
5 on the position-control cam bar 21a in the vicinity of the front end thereof. The guide key 21e is formed to have a cross section shape allowed to enter the guide key insertable recess 37g in the optical axis direction.

Operations of the second lens group LG2, the third  
10 lens group LG3 and other associated elements, which are supported by the above described accommodating structure including a structure retracting the second lens frame 6 to the radially retracted position thereof, will be hereinafter discussed. The position of the second lens  
15 group moving frame 8 with respect to the CCD holder 21 in the optical axis direction is determined by a combination of the axial movement of the cam ring 11 by the cam diagrams of the plurality of inner cam grooves 11a (11a-1 and 11a-2) and the axial movement of the cam  
20 ring 11 itself. The second lens group moving frame 8 is positioned farthest from the CCD holder 21 when the zoom lens 71 is set at about the wide-angle extremity as shown above the photographing optical axis Z1 in Figure 9, and is positioned closest to the CCD holder 21 when the zoom  
25 lens 71 is in the retracted state as shown in Figure 10.

The second lens frame 6 is retracted to the radially retracted position thereof by utilizing the retracting rearward movement of the second lens group moving frame 8 from the frontmost axial portion thereof (wide-angle 5 extremity) to the rearmost axial position thereof (retracted position).

In the zooming range between the wide-angle extremity and the telephoto extremity, the second lens frame 6 is held still at a fixed position by the engagement 10 of the tip of the engaging protrusion 6e with the eccentric pin 35b of the rotation limit shaft 35 as shown in Figure 111. At this time, the optical axis of the second lens group LG2 is coincident with the photographing optical axis Z1, so that the second lens frame 6 is in a 15 photographing position thereof. When the second lens frame 6 is in a photographing position thereof as shown in Figure 111, a part of the position control arm 6j and the rear movable spring end 40b of the rear torsion coil spring 40 are exposed to the rear of the second lens group 20 moving frame 8 through the cam-bar insertable hole 37c.

Upon the main switch of the digital camera 70 being turned OFF in the ready-to-photograph state of the zoom lens 71, the control circuit 140 drives the AF motor 160 in the lens barrel retracting direction to move the AF 25 lens frame 51 rearward, toward the CCD holder 21 to a

rearmost position (retracted position) thereof as shown in Figures 121, 123 and 124. The forwardly-projecting lens holder portion 51c holds the third lens group LG3 therein in the vicinity of the front end surface 51c1.

5      The space immediately behind the third lens group LG3 is provided as an open space surrounded by the four side surfaces 51c3, 51c4, 51c5 and 51c6 so that the low-pass filter LG4 and the CCD image sensor 60, which are supported by the CCD holder 21 (the filter holder portion 21b), can

10     enter the space immediately behind the third lens group LG3 so as to reduce the space between the third lens group LG3 and the low-pass filter LG4 when the AF lens frame 51 is retracted to the rearmost position. In a state where the AF lens frame 51 is in the rearmost position

15     as shown in Figure 10, the front end of the position-control cam bar 21a is positioned in front of the AF lens frame 51 in the optical axis direction.

Subsequently, the control circuit 140 drives the zoom motor 150 in the lens barrel retracting direction

20     to perform the above described lens barrel retracting operation. Keep driving the zoom motor 150 in the lens barrel retracting direction beyond the wide-angle extremity of the zoom lens 71 causes the cam ring 11 to move rearward in the optical axis direction while rotating

25     about the lens barrel axis Z0 due to engagement of the

set of three roller followers 32 with the set of three through-slots 14e, respectively. As can be understood from the relationship shown in Figure 17 between the plurality of inner cam grooves 11a and the plurality of 5 cam followers 8b, even though the second lens group moving frame 8 is positioned closer to the front of the zoom lens 71 in the optical axis direction relative to the cam ring 11 when the zoom lens 71 is in the retracted position than that when the zoom lens 71 is in the wide-angle extremity, 10 the second lens group moving frame 8 comes near the CCD holder 21 when the zoom lens 71 is in the retracted state because the amount or rearward movement of the cam ring 11 relative to the stationary barrel 22 is greater than the amount of forward movement of the second lens group 15 moving frame 8 in the cam ring 11 relative to the cam ring 11 in the lens barrel retracting operation.

A further retracting movement of the second lens group moving frame 8 together with the second lens frame 6 causes the front end of the position-control cam bar 20 21a to enter the cam-bar insertable hole 37c (see Figure 105). As described above, a part of the position control arm 6j and the rear movable spring end 40b of the rear torsion coil spring 40 are exposed to the rear of the second lens group moving frame 8 through the cam-bar 25 insertable hole 37c as shown in Figure 111. Figure 118

shows the positional relationship at this time among the position control arm 6j, the rear movable spring end 40b and the position-control cam bar 21a, viewed from the front of the zoom lens 71. The rear movable spring end 5 40b is positioned closer to the position-control cam bar 21a than the position control arm 6j (except for a protrusion formed thereon for the formation of the first spring engaging hole 6k) in a radial direction of the photographing optical axis Z1. On the other hand, the 10 retracting cam surface 21c is formed as an inclined surface which is inclined forward in a direction away from the photographing optical axis Z1. A frontmost portion of the retracting cam surface 21c is positioned immediately behind the rear movable spring end 40b of the 15 rear torsion coil spring 40 in the state shown in Figure 118. A rearward movement of the second lens frame 6 together with the second lens group moving frame 8 toward the CCD holder 21 with the positional relationship shown in Figure 118 being maintained causes the retracting cam 20 surface 21c to come into contact with the rear movable spring end 40b, not the position control arm 6j of the second lens frame 6. Figure 123 shows the position of the second lens frame 6 at the time immediately before the rear movable spring end 40b comes into contact with 25 the retracting cam surface 21c.

A further rearward movement of the second lens frame 6 together with the second lens group moving frame 8 with the rear movable spring end 40b remaining in contact with the retracting cam surface 21c causes the rear movable 5 spring end 40b to slide on the retracting cam surface 21c in a clockwise direction as viewed in Figure 118 in accordance with the shape of the retracting cam surface 21c. This clockwise rotation of the rear movable spring end 40b is transferred to the second lens group 6 via the 10 front stationary spring end 40a. The spring force (rigidity) of the rear torsion coil spring 40 is predetermined to be capable of transferring a torque from the rear movable spring end 40b to the second lens group 6 via the front stationary spring end 40a without the front 15 stationary spring end 40a and the rear movable spring end 40b being further pressed to move in opposite directions approaching each other than those shown in Figures 118 through 120. Namely, the resiliency of the rear torsion coil spring 40 is determined to be greater than that of 20 the front torsion coil spring 39 at the time the front torsion coil spring 39 holds the second lens frame 6 in the photographing position.

Upon receiving a turning force from the retracting cam surface 21c via the rear torsion coil spring 40, the 25 second lens group 6 rotates about the pivot shaft 33

against the spring force of the front torsion coil spring 39 from the photographing position shown in Figure 111 toward the radially retracted position shown in Figure 112 in accordance with the retracting movement of the 5 second lens group moving frame 8. With this rotation of the second lens group 6, the rear movable spring end 40b of the rear torsion coil spring 40 slides on the retracting cam surface 21c from the position shown in Figure 118 to the position shown in Figure 119. Upon the second lens 10 frame 6 rotating to the radially retracted position shown in Figure 112, the rear movable spring end 40b moves from the retracting cam surface 21c to the removed-position holding surface 21d to be engaged therewith. Thereafter, the second lens frame 6 is not rotated about the pivot 15 shaft 33 in a direction to the radially retracted position by a retracting movement of the second lens group moving frame 8. In a state where the second lens frame 6 is held in the radially retracted position as shown in Figure 112, an outer peripheral portion of the cylindrical lens holder 20 portion 6a enters the radial recess 8q while an outer edge of the engaging protrusion 6e enters the second radial recess 8r of the second lens group moving frame 8.

After the second lens frame 6 reaches the radially retracted position, the second lens group moving frame 25 8 continues to move rearward until reaching the retracted

position shown in Figure 10. During this rearward movement of the second lens group moving frame 8, the second lens group 6 moves rearward together with the second lens group moving frame 8 to the position shown 5 in Figure 124 with the second lens group 6 held in the radially retracted position, in which the rear movable spring end 40b remains in engaged with the retracting cam surface 21c. At this time, the front end of the position-control cam bar 21a projects forward from the 10 cam-bar insertable hole 37c through the cam-bar insertable hole 36c and the pivoted cylindrical portion receiving hole 8g.

As shown in Figures 10 and 124, in the retracted state of the zoom lens 71, the cylindrical lens holder portion 6a of the second lens frame 6 has moved into the space immediately above the forwardly-projecting lens holder portion 51c, the forwardly-projecting lens holder portion 51c has moved into that space in the second lens group moving frame 8 in which the second lens group LG2 20 is positioned in the ready-to-photograph state of the zoom lens 71, and the third lens group LG3 is positioned immediately behind the shutter unit 76. In addition, the low-pass filter LG4 and the CCD image sensor 60 have entered the forwardly-projecting lens holder portion 51c 25 from the rear thereof by a rearward movement of the

forwardly-projecting lens holder portion 51c, and accordingly, the space between the third lens group LG3 and the low-pass filter LG4 and also the space between the third lens group LG3 and the CCD image sensor 60 in 5 the optical axis direction are smaller in the retracted state of the zoom lens 71 than those in the ready-to-photograph state of the zoom lens 71 as can be seen by making a comparison between Figures 9 and 10. Namely, in the retracted state of the zoom lens 71, the second 10 lens group LG2 is positioned in the space radially outside the space in which the third lens group LG3, the low-pass filter LG4 and the CCD image sensor 60 are positioned. In a conventional photographing lens barrel including a plurality of optical elements in which one or more movable 15 optical elements thereof are moved only along a photographing optical axis, it is impossible to make the length of the photographing lens barrel smaller than the sum of the thicknesses of all the plurality of optical elements. However, according to the accommodating 20 structure of the zoom lens 71, it is substantially unnecessary to secure any space for accommodating the second lens group LG2 on the photographing optical axis 21. This makes it possible to make the length of the zoom lens 71 smaller than the sum of the thicknesses of all 25 the plurality of optical elements of the zoom lens 71.

In the present embodiment of the zoom lens, the AF lens frame 51 has various features in its shape and supporting structure that make it possible to retract the zoom lens 71 in the camera body 72 in a highly space-saving fashion. Such features will be hereinafter discussed in detail.

The AF guide shaft 52, which serves as a main guide shaft for guiding the AF lens frame 51 in the optical axis direction with a high positioning accuracy, and the AF guide shaft 53, which serves as an auxiliary guide shaft for secondarily guiding the AF lens frame 51 in the optical axis direction, are positioned outside cylindrical wall 22k of the stationary barrel 22 on radially opposite sides of the photographing optical axis Z1 (at positions not interfering with any of the movable lens groups of the zoom lens 71). This structure of the AF lens frame 51 contributes to a reduction of the length of the zoom lens 71 when the zoom lens 71 is retracted into the camera body 72 because neither the AF guide shaft 52 nor the AF guide shaft 53 becomes an obstruction which interferes with one or more of the first through third lens groups LG1, LG2 and LG3 and the low-pass filter LG4.

In other words, according to such a structure of the AF lens frame 51, since the pair of AF guide shafts 52 and 53 can be disposed freely without being subject to

constraints by moving parts positioned in the stationary barrel 22 such as the second lens frame 6, the effective length of each of the AF guide shafts 52 and 53 for guiding the AF lens frame 51 in the optical axis direction can 5 be made long enough to guide the AF lens frame 51 in the optical axis direction with a high positioning accuracy. As can be seen in Figures 9 and 10, the LCD panel 20 is positioned immediately behind the zoom lens barrel 71 (on a rearward extension line of the optical axis Z1) while 10 the pair of AF guide shafts 52 and 53 are positioned outside the LCD panel 20 in radial directions of the lens barrel axis Z0. This arrangement achieves the pair of AF guide shafts 52 and 53 having long axial lengths which are largely extended even toward the rear of the camera body 72 without interfering with the LCD panel 20 that 15 is comparatively large in dimension. In practice, the rear end of the AF guide shaft 52 is extended to a position below the LCD panel 20 in the camera body 72 as shown in Figure 9.

20        Additionally, an annular space which is surrounded by the outer peripheral surface of the forwardly-projecting lens holder portion 51c, the first arm portion 51d, the second arm portion 51e and the inner peripheral surface of the stationary barrel 22 (the AF guide shafts 25 52 and 53) is secured due to the structure wherein the

AF lens frame 51 is shaped so that the first arm portion 51d extends radially outwards from the rear end of the corner of the forwardly-projecting lens holder portion 51c between the two side surfaces 51c3 and 51c6 and so 5 that the second arm portion 51e extends radially outwards from the rear end of the corner of the forwardly-projecting lens holder portion 51c between the two side surfaces 51c4 and 51c5. This annular space is used to accommodate not only the second lens group LG2 but also 10 rear end portions of annular members such as the first through third external barrels 12, 13 and 15 and the helicoid ring 18 to maximize the utilization of the internal space of the camera body 72. Moreover, the annular space contributes to a further retraction of the 15 zoom lens 71 in the camera body 72 (see Figure 10). If the AF lens frame 51 does not have the above described space-saving structure, e.g., if each of the first and second arm portions 51d and 51e is formed on the forwardly-projecting lens holder portion 51c to extend 20 radially from an axially intermediate portion or an axially front end portion thereof unlike the present embodiment of the zoom lens, such elements as the second lens group L2 cannot be retracted to their respective positions shown in Figure 10.

25 In addition, in the present embodiment of the zoom

lens, the AF lens frame 51 is constructed so that the third lens group LG3 is supported by the forwardly-projecting lens holder portion 51c in a front end space thereof and so that the low-pass filter LG4 and the CCD image sensor 5 60 are accommodated in the space in the rear of the forwardly-projecting lens holder portion 51c in the retracted state of the zoom lens 71. This further maximizes the utilization of the internal space of the zoom lens 71.

10       Upon the main switch of the digital camera 70 being turned ON in the retracted state of the zoom lens 71, the control circuit 140 drives the AF motor 160 in the lens barrel advancing direction so that the above described moving parts operate in the reverse manner to the above 15 described retracting operations. The cam ring 11 advances while rotating relative to the first linear guide ring 14 and at the same time the second lens group moving frame 8 and the first external barrel 12 advance together with the cam ring 11 without rotating relative to the first 20 linear guide ring 14. At an initial stage of the advancement of the second lens group moving frame 8, the second lens frame 6 remains in the radially retracted position since the rear movable spring end 40b is still engaged with the removed-position holding surface 21d. 25 A further forward movement of the second lens group moving

frame 8 causes the rear movable spring end 40b to firstly reach the front end of the position-control cam bar 21a and subsequently be disengaged from the removed-position holding surface 21d to be engaged with the retracting cam 5 surface 21c as shown in Figure 120. At this stage, the cylindrical lens holder portion 6a of the second lens frame 6 has moved ahead of the forwardly-projecting lens holder portion 51c in the optical axis direction, so that the cylindrical lens holder portion 6a does not interfere 10 with the forwardly-projecting lens holder portion 51c even if the second lens frame 6 commences to rotate about the pivot shaft 33 in a direction to the photographing position. A further forward movement of the second lens group moving frame 8 causes the rear movable spring end 15 40b to slide on the retracting cam surface 21c so that the second lens frame 6 starts rotating from the radially retracted position to the photographing position by the spring force of the front torsion coil spring 39.

A further forward movement of the second lens group 20 moving frame 8 firstly causes the rear movable spring end 40b to keep sliding on the retracting cam surface 21c in a direction away from the removed-position holding surface 21d (left to right as viewed in Figure 118), and subsequently causes the rear movable spring end 40b to 25 be disengaged from the retracting cam surface 21c upon

the rear movable spring end 40b moving to a predetermined point on the retracting cam surface 21c. At this time, the relative position between the rear movable spring end 40b and the retracting cam surface 21c as viewed from front 5 of the second lens frame 6 corresponds to that shown in Figure 118. As a result, the second lens frame 6 becomes totally free from the constraint of the position-control cam bar 21a. Consequently, the second lens frame 6 is held in the photographing position as shown in Figure 111 10 with the tip of the engaging protrusion 6e being in pressing contact with the eccentric pin 35b of the rotation limit shaft 35 by the spring force of the front torsion coil spring 39. Namely, the optical axis of the second lens group LG2 coincides with the photographing 15 optical axis z1. The second lens frame 6 finishes rotating from the radially retracted position to the photographing position by the time the zoom lens 71 has been extended to the wide-angle extremity when the main switch of the digital camera 70 is turned ON.

20 Although the AF lens frame 51 moves forward from its rearmost position when the zoom lens 71 changes from the retracted state shown in Figure 10 to the ready-to-photograph state shown in Figure 9, the forwardly-projecting lens holder portion 51c still covers the front 25 of the low-pass filter LG4 and the CCD image sensor 60

even in the ready-to-photograph state shown in Figure 9 so that the front end surface 51c1 and the four side surfaces 51c3, 51c4, 51c5 and 51c6 can prevent unnecessary light such as stray light from being incident on the 5 low-pass filter LG4 and the CCD image sensor 60 through any part other than the third lens group LG3. Accordingly, the forwardly-projecting lens holder portion 51c of the AF lens frame 51 serves as not only a member for supporting the third lens group LG3 but also a member for 10 accommodating the low-pass filter LG4 and the CCD 60 in the retracted state of the zoom lens 71, and also a light shield member for preventing unnecessary light such as stray light from being incident on the low-pass filter LG4 and the CCD image sensor 60 in the ready-to-photograph 15 state of the zoom lens 71.

In general, a structure supporting a movable lens group of a photographing lens system must be precise so as not to deteriorate the optical performance of the photographing lens system. In the present embodiment of 20 the zoom lens, each of the second lens frame 6 and the pivot shaft 33, in particular, is required to have high dimensional accuracy which is several orders of magnitude higher than those of simple movable elements since the second lens group LG2 is driven to not only move along 25 the photographing optical axis z1 but also rotate to

retract to the radially retracted position. For instance, with the shutter unit 76 (having exposure control devices such as the shutter S and the diaphragm A) provided inside the second lens group moving frame 8, if a pivot shaft 5 corresponding to the pivot shaft 33 is provided in front of or behind the shutter unit 76, the length of the pivot shaft would be limited, or would make the pivot shaft act as a cantilever type pivot shaft. Nevertheless, since it is necessary to secure a minimum clearance allowing 10 the pivot shaft (such as the pivot shaft 33) and a through hole (such as the through hole 6d) into which the pivot shaft is fitted to rotate relative to each other, such a clearance may cause the axis of the through hole to tilt relative to the axis of the pivot shaft if the pivot shaft 15 is a short shaft or a cantilever pivot shaft. Even if within tolerance in a conventional lens supporting structure, such a tilt must be prevented from occurring in the present embodiment of the zoom lens because each of the second lens frame 6 and the pivot shaft 33 is 20 required to have a very high dimensional accuracy.

In the above described retracting structure for the second lens frame 6, since it can be seen in Figures 108, 109 and 113 that the front second lens frame support plate 36 and the rear second lens frame support plate 37 are 25 respectively fixed to the front fixing surface 8c and the

rear fixing surface 8e, which are respectively positioned on front and rear of the shutter unit 76 in the optical axis direction, and that the pivot shaft 33 is disposed to extend between the front second lens frame support plate 36 and the rear second lens frame support plate 37, both the front end and the rear end of the pivot shaft 33 are supported by the front second lens frame support plate 36 and the rear second lens frame support plate 37, respectively. Accordingly, the axis of the pivot shaft 33 does not easily tilt with respect to the axis of the through hole 6d of the second lens frame 6. Moreover, the pivot shaft 33 can be lengthened regardless of the shutter unit 76 (without interfering with the shutter unit 76) since the front second lens frame support plate 36, the rear second lens frame support plate 37 and the pivoted cylindrical portion receiving hole 8g, which serve as elements of the structure supporting the pivot shaft 33, are positioned not to overlap the shutter unit 76. In fact, the pivot shaft 33 is elongated so that the length thereof becomes close to the length of the second lens group moving frame 8 in the optical axis direction. In accordance with the length of the pivot shaft 33, the pivoted cylindrical portion 6b is elongated in the optical axis direction. Namely, a wide range of engagement in the axial direction is secured between the pivoted

cylindrical portion 6b and the pivot shaft 33. With this structure, there is little possibility of the second lens frame 6 from tilting with respect to the pivot shaft 33, which makes it possible to rotate the second lens frame 6 about the pivot shaft 33 with a high degree of positioning accuracy.

The front boss 8j and the rear boss 8k that project from the front fixing surface 8c and the rear fixing surface 8e determine the position of the front second lens frame support plate 36 and the position of the rear second lens frame support plate 37, respectively, and the front and rear second lens frame support plates 36 and 37 are firmly fixed to the second lens group moving frame 8 by the common set screw 66. With this structure, the front and rear second lens frame support plates 36 and 37 are positioned relative to the second lens group moving frame 8 with a high degree of positioning accuracy. Therefore, the pivot pin 33 is also positioned relative to the second lens group moving frame 8 with a high degree of positioning accuracy.

In the present embodiment of the zoom lens, the set of three extensions 8d are formed on the front end surface of the second lens group moving frame 8 in front of the front fixing surface 8c, whereas the rear fixing surface 8e is flush with the rear end surface of the second lens

group moving frame 8. Namely, the front fixing surface 8c is not formed on the frontmost end surface of the second lens group moving frame 8. However, if the second lens group moving frame 8 is formed as a simple cylindrical member having no projections such as the set of three extensions 8d, the front and rear second lens frame support plates 36 and 37 can be fixed to frontmost and rearmost end surfaces of the simple cylindrical member, respectively.

10 In the above described retracting structure for the second lens frame 6, if the range of movement of the second lens group moving frame 8 in the optical axis direction from the position corresponding to the wide-angle extremity to the retracted position is fully used to 15 rotate the second lens frame 6 about the pivot shaft 33 from the photographing position to the radially retracted position, the second lens frame 6 will interfere with the forwardly-projecting lens holder portion 51c of the AF lens frame 51 on the way to the radially retracted position.  
20 To prevent this problem from occurring, in the above described retracting structure for the second lens frame 6, the second lens frame 6 finishes rotating to the radially retracted position within an axial range of movement sufficiently shorter than the range of movement 25 of the second lens group moving frame 8 in the optical

axis direction, and subsequently the cylindrical lens holder portion 6a of the second lens frame 6 moves rearward in parallel in the optical axis direction to the space immediately above the forwardly-projecting lens holder portion 51c. Therefore, the space for the parallel displacement of the cylindrical lens holder portion 6a to the space immediately above the forwardly-projecting lens holder portion 51c must be secured in the zoom lens 71. In order for the second lens frame 8 to secure a sufficient range of rotation from the photographing position to the radially retracted position within a short range of movement in the optical axis direction, it is necessary to increase the inclination of the retracting cam surface 21c, that is formed on the front end of the position-control cam bar 21a of the CCD holder 21, with respect to the direction of movement of the second lens group moving frame 8, i.e., with respect to the optical axis direction. While the retracting cam surface 21c that is formed in such a manner presses the rear movable spring end 40b during the rearward movement of the second lens group 8, a great reaction force is exerted on the position-control cam bar 21a and the second lens group moving frame 8; such a reaction force is greater than that in the case where a cam surface (which corresponds to the cam surface 21c) the inclination of which with respect

to the direction of movement of the second lens group moving frame 8 is small presses the rear movable spring end 40b during the rearward movement of the second lens group 8.

5       The position-control cam bar 21a is a fixed member just like the stationary barrel 22, whereas the second lens group moving frame 8 is a linearly movable member; the second lens group moving frame 8 is guided linearly without rotating about the lens barrel axis Z0 indirectly  
10 by the stationary barrel 22 via such intermediate members as the first and second linear guide rings 14 and 10, not directly by the stationary barrel 22. A clearance exists in each of the following two engagements: the engagement of the second lens group moving frame 8 with the second  
15 linear guide ring 10 and the engagement of the second linear guide ring 10 with the second linear guide ring 14. Due to this reason, it has to be taken into account that such clearances may cause the second lens group moving frame 8 and the CCD holder 21 to become misaligned  
20 in the plane orthogonal to the lens barrel axis Z0 to thereby exert an adverse effect on the retracting operation for the second lens frame 6 from the photographing position to the radially retracted position if a great reaction force is exerted on the position-control cam bar  
25 21a and the second lens group moving frame 8. For

instance, if the second lens frame 6 rotates beyond an original radial-outer limit thereof (see Figure 112) for the rotational movement of the second lens frame 6 about the pivot shaft 33 when rotated from the photographing position to the radially retracted position, the cylindrical lens holder portion 6a may interfere with an inner peripheral surface of the second lens group moving frame 8. Likewise, if the second lens frame 6 stops rotating before the original radial-outer limit when rotated from the photographing position to the radially retracted position, i.e., if the second lens frame 6 does not rotate to the original radial-outer limit when rotated from the photographing position to the radially retracted position, the cylindrical lens holder portion 6a may interfere with the AF lens frame 51 and others.

The position-control cam bar 21a and the second lens group moving frame 8 are prevented from being misaligned by inserting the guide key 21e into the guide key insertable recess 37g to hold the second lens frame 6 precisely in the radially retracted position when the second lens frame 6 rotates from the photographing position to the radially retracted position (see Figure 106). Specifically, when the second lens group moving frame 8 is in the process of retracting toward the retracted position with the second lens frame 6 having

been held in the radially retracted position by the engagement of the rear movable spring end 40b of the rear torsion coil spring 40 with the removed-position holding surface 21d, the guide key 21e enters the key way 8p of 5 the second lens group moving frame 8 from the rear end thereof through the guide key insertable recess 37g. Since the guide key 21e and the key way 8p are an elongated projection and an elongated groove which extend in the optical axis direction, the guide key 21e is freely 10 movable relative to the key way 8p in the optical axis direction and prevented from moving in a widthwise direction of the key way 8p when the guide key 21e is engaged in the key way 8p. Due to this structure, even 15 if a comparatively great reaction force is exerted on the second lens group moving frame 8 while the retracting cam surface 21c presses the rear movable spring end 40b, the engagement of the guide key 21e with the key way 8p prevents the second lens group moving frame 8 and the position-control cam bar 21a from being misaligned in the 20 plane orthogonal to the lens barrel axis ZO. Consequently, the second lens frame 6 is held precisely in the radially retracted position when the second lens frame 6 rotates from the photographing position to the radially retracted position.

25           Although the guide key 21e commences to be engaged

in the key way 8p after the second lens frame 6 has been rotated to the radially retracted position in the present embodiment of the zoom lens, the guide key 21e can commence to be engaged in the key way 8p before the second lens frame 6 has been rotated to the radially retracted position or during the retracting movement of the second lens frame 6 toward the radially retracted position. In short, the second lens group moving frame 8 and the position-control cam bar 21a have only to be precisely aligned at the time when the second lens frame 6 is held in the radially retracted position after all. The timing of commencement of the engagement between the guide key 21e with the key way 8p can be freely determined by, e.g., changing the axial range of formation of the guide key 21e in the optical axis direction.

It is possible that the guide key 21e and the key way 8p be replaced by a key way corresponding to the key way 8p and a guide key corresponding to the guide key 21e, respectively.

Although the guide key 21e is formed on the position-control cam bar 21a which includes the retracting cam surface 21c in the above illustrated embodiment, an element corresponding to the guide key 21e can be formed on any portion on the CCD holder 21 other than the position-control cam bar 21a. However, from a

structural point of view, it is desirable that the guide key 21e be formed together with the retracting cam surface 21c on the position-control cam bar 21a. In addition, to align the second lens group moving frame 8 and the 5 position-control cam bar 21a precisely, it is desirable that the guide key 21e be formed on the position-control cam bar 21a which serves as an engaging portion which is engageable with the second lens frame 6 through the side second lens group moving frame 8.

10 Not only the aforementioned reaction force which is exerted on the second lens group moving frame 8 while the retracting cam surface 21c presses the rear movable spring end 40b, but also the positioning accuracy of each element of the retracting structure for the second lens frame 6 15 exert an adverse influence on the operating accuracy of the second lens frame 6. As described above, it is undesirable if the range of rotation of the second lens frame 6 about the pivot shaft 33 from the photographing position to the radially retracted position is either 20 excessive or insufficient. However, if a force which may retract the second lens frame 6 beyond the radially retracted position shown in Figure 112 is applied to the second lens frame 6, a mechanical stress is applied to the retracting structure for the second lens frame 6 25 because cylindrical lens holder portion 6a and the

engaging protrusion 6e are brought very close to an inner peripheral surface of the second lens group moving frame 8 in the retracted state of the zoom lens 71 to achieve a space-saving retracting structure for the second lens frame 6 (see Figure 112). Accordingly, it is required to prevent such a mechanical stress from being applied to the retracting structure for the second lens frame 6.

To prevent such mechanical stress from being applied to the retracting structure for the second lens frame 6, 10 rather than the position control arm 6j of the pivoted cylindrical portion, the rear movable spring end 40b of the rear torsion coil spring 40 serves as a portion which is to be engageable with the retracting cam surface 21c and the removed-position holding surface 21d when the 15 second lens frame 6 retracts from the photographing position to the radially retracted position so that a slight error in movement of the second lens group 6 is absorbed by a resilient deformation of the rear torsion coil spring 40. Although the rear torsion coil spring 20 40 transfers a torque from the rear movable spring end 40b to the second lens group 6 via the front stationary spring end 40a without the front stationary spring end 40a and the rear movable spring end 40b being further pressed to move in opposite directions approaching each 25 other than those shown in Figures 118 through 120 as

mentioned above in a normal retracting operation of the zoom lens 71, the rear movable spring end 40b is further pressed to move in a direction approaching the front stationary spring end 40a than the rear movable spring 5 end 40b shown in Figures 118 through 120 within the range q1 shown in Figure 120 if the position-control cam bar 21a slightly deviates leftward, as viewed in Figure 120 from the original position shown in Figure 120, since the rear movable spring end 40b is allowed to move in the first 10 spring engaging hole 6k in the range q1 as mentioned above. Accordingly, such a movement of the rear movable spring end 40b within the range NR1 can absorb the deviation of the position-control cam bar 21a from the original position thereof. Namely, even if the position-control 15 cam bar 21a further presses the rear movable spring end 40b in a state where the cylindrical lens holder portion 6a and the engaging protrusion 6e are in contact with an inner peripheral surface of the second lens frame moving frame 8 (in a state where an outer peripheral portion of 20 the cylindrical lens holder portion 6a and an outer edge of the engaging protrusion 6e have entered the radial recess 8q and the second radial recess 8r, respectively), an excessive mechanical stress is prevented from being applied to the retracting structure for the second lens 25 frame 6 by a resilient deformation of the rear torsion

coil spring 40.

In the retracting structure for the second lens frame 6, when the second lens frame 6 is in the radially retracted position as shown in Figure 112, a radially outside surface of the swing arm portion 6c is positioned to adjoin the bottom of the wide guide groove 8a-W to partly close the bottom of the wide guide groove 8a-W. In other words, the bottom of the wide guide groove 8a-W is formed on the radially outside of an intermediate point of a line extending between the axis of the pivot shaft 33 and the retracted optical axis Z2 of the second lens group LG2, and a part of the flexible PWB 77 is positioned in the wide guide groove 8a-W. Due to this structure, the swing arm portion 6c supports this part of the flexible PWB 77 from inside the second lens group moving frame 8 as shown in Figure 112 when the second lens frame 6 is positioned in the radially retracted position. Figure 126 shows the flexible PWB 77 and the second lens frame 6 by solid lines when the second lens frame 6 is positioned in the radially retracted position, and shows the second lens frame 6 by two-dot chain lines when the second lens frame 6 is positioned in the photographing position. It can be understood from Figure 126 that the swing arm portion 6c prevents the flexible PWB 77 from curving radially inwards by pushing the first straight portion

77a and the loop-shaped turning portion 77b of the flexible PWB 77 radially outwards

Specifically, the swing arm portion 6c is provided on a radially outer surface thereof with a straight flat 5 surface 6q, and is further provided immediately behind the straight flat surface 6q with an oblique surface 6r. The rear projecting portion 6m projects rearward in the optical axis direction from a portion of the swing arm portion 6c immediately behind the straight flat surface 10 6q (see Figure 105). In the retracted state of the zoom lens 71, the straight flat surface 6q pushes the first straight portion 77a radially outwards while the oblique surface 6r and the rear projecting portion 6m push the loop-shaped turning portion 77b radially outwards. The 15 oblique surface 6r is inclined to correspond to a curve of the loop-shaped turning portion 77b.

In typical retractable lenses, in the case where a flexible PWB extends between a movable element guided in an optical axis direction and a fixed element, the 20 flexible PWB needs to be sufficiently long to cover the full range of movement of the movable element. Therefore, the flexible PWB tends to sag when the amount of advancement of the movable element is minimum, i.e., when the retractable lens is in the retracted state. Such a 25 tendency of the flexible PWB is especially strong in the

present embodiment of the zoom lens because the length of the zoom lens 71 is greatly reduced in the retracted state thereof by retracting the second lens group so that it is positioned on the retracted optical axis Z2 and also

5 by adopting a three-stage telescoping structure for the zoom lens 71. Since interference of any sag of the flexible PWB with internal elements of the retractable lens or jamming of a sagging portion of the flexible PWB into internal elements of the retractable lens may cause

10 a failure of the retractable lens, it is necessary for the retractable lens to be provided with a structure preventing such problems associated with the flexible PWB from occurring. However, this preventing structure is generally complicated in conventional retractable lenses.

15 In the present embodiment of the zoom lens 71, in the view of the fact that the flexible PWB 77 tends to sag when the zoom lens 71 is in the retracted state, the loop-shaped turning portion 77b is pushed radially outwards by the second lens frame 6 positioned in the radially

20 retracted position, which reliably prevents the flexible PWB 77 from sagging with a simple structure.

In the retracting structure for the second lens frame 6 in the present embodiment of the zoom lens, the moving path of the second lens frame 6 from the

25 photographing position to the radially retracted

position extends obliquely from a point (front point) on the photographing optical axis Z1 to a point (rear point) behind the front point and above the photographing optical axis Z1 because the second lens frame 6 moves rearward 5 in the optical axis direction while rotating about the pivot shaft 33. On the other hand, the AF lens frame 51 is provided thereon between the front end surface 51c1 and the side surface 51c5 with a recessed oblique surface 51h. The recessed oblique surface 51h is inclined in a 10 radially outward direction from the photographing optical axis Z1 from front to rear of the optical axis direction. The edge of the forwardly-projecting lens holder portion 51c between the front end surface 51c1 and the side surface 51c5 is cut out along a moving path of 15 the cylindrical lens holder portion 6a so as to form the recessed oblique surface 51h. Moreover, the recessed oblique surface 51h is formed as a concave surface which corresponds to the shape of an associated outer surface of the cylindrical lens holder portion 6a.

20 As described above, the AF lens frame 51 moves rearward to the rear limit for the axial movement thereof (i.e., the retracted position), at which the AF lens frame 51 (forwardly-projecting lens holder portion 51c) comes into contact with the filter holder portion 21b (stop 25 surface), before the commencement of retracting movement

of the second lens frame 6 from the photographing position to the radially retracted position. In the state shown in Figure 123 in which the AF lens frame 51 is in contact with the filter holder portion 21b while the second lens frame 6 has not commenced to retract from the photographing position to the radially retracted position, if the second lens frame 6 starts moving rearward in the optical axis direction while rotating about the pivot shaft 33 to retract to the radially retracted position, the rear end of the cylindrical lens holder portion 6a firstly moves obliquely rearward while approaching the recessed oblique surface 51h, and subsequently further moves obliquely rearward while just missing (passing closely across) the recessed oblique surface 51h to finally reach a fully retracted position shown in Figure 124. Namely, the retracting operation for the second lens frame 6 from the photographing position to the radially retracted position can be performed at a closer point to the AF lens frame 51 in the optical axis direction substantially by the amount by which the oblique surface 51h is recessed.

If the recessed oblique surface 51h or a similar surface is not formed on the AF lens frame 51, the retracting operation for the second lens frame 6 from the photographing position to the radially retracted

position has to be completed at an earlier stage than that  
in the illustrated embodiment to prevent the cylindrical  
lens holder portion 6a from interfering with the AF lens  
frame 51. To this end, it is necessary to increase the  
5 amount of rearward movement of the second lens group  
moving frame 8 or the amount of projection of the  
position-control cam bar 21a from the CCD holder 22; this  
runs counter to further miniaturization of the zoom lens  
71. If the amount of rearward movement of the second lens  
10 group moving frame 8 is fixed, the inclination of the  
retracting cam surface 21c with respect to the  
photographing axis direction has to be increased.  
However, if this inclination is excessively large, the  
reaction force which is exerted on the position-control  
15 cam bar 21a and the second lens group moving frame 8 while  
the retracting cam surface 21c presses the rear movable  
spring end 40b is increased. Accordingly, it is  
undesirable that the inclination of the retracting cam  
surface 21c be increased to prevent a jerky motion from  
20 occurring in the retracting operation for the second lens  
frame 6. In contrast, in the present embodiment of the  
zoom lens, the retracting movement of the second lens  
frame 6 from the photographing position to the radially  
retracted position can be performed even after the AF lens  
25 frame 51 has retracted at a point very close to the AF

lens frame 51 due to the formation of the recessed oblique surface 51h. Therefore, even if the amount of rearward movement of the second lens group moving frame 8 is limited, the retracting cam surface 21c does not have to be shaped 5 to be inclined largely with respect to the optical axis direction. This makes it possible to achieve further miniaturization of the zoom lens 71 with a smoothing of the retracting movement of the second lens group moving frame 8. Similar to the AF lens frame 51, the CCD holder 10 21 is provided on a top surface thereof behind the recessed oblique surface 51h with a recessed oblique surface 21f the shape of which is similar to the shape of the recessed oblique surface 51h. The recessed oblique surface 51h and the recessed oblique surface 21f are successively 15 formed along a moving path of the cylindrical lens holder portion 6a to be shaped like a single oblique surface. Although the AF lens frame 51 serves as a movable member guided in the optical axis direction in the illustrated embodiment, a lens frame similar to the AF lens frame 51 20 can be provided with a recessed oblique surface corresponding to the recessed oblique surface 51h to incorporate features similar to the above described features of the recessed oblique surface 51h even if the lens frame similar to the AF lens frame 51 is of a type 25 which is not guided in an optical axis direction.

As can be understood from the above descriptions, the retracting structure for the second lens frame 6 is designed so that the second lens frame 6 does not interfere with the AF lens frame 51 when moving rearwards while 5 retracting radially outwards to the radially retracted position in a state where the AF lens frame 51 has retracted to the rear limit (the retracted position) for the axial movement of the AF lens frame 51 as shown in Figures 123 and 124. In this state, upon the main switch 10 being turned OFF, the control circuit 140 drives the AF motor 160 in the lens barrel retracting direction to move the AF lens frame 51 rearward the retracted position thereof. However, if the AF lens frame 51 does not retract to the retracted position accidentally for some 15 reason upon the main switch being turned OFF, the AF lens frame 51 may interfere with the moving path of the second lens group 6 which is in the middle of moving rearward together with the second lens group moving frame 8 while rotating to the radially retracted position (see Figures 20 127 and 129).

To prevent such a problem from occurring, the zoom lens 71 is provided with a fail-safe structure. Namely, the second lens frame 6 is provided on the swing arm portion 6c with the rear projecting portion 6m that 25 projects rearward, beyond the rear end of the second lens

group LG2, in the optical axis direction, while the AF lens frame 51 is provided, on that portion of the front end surface 51c1 of the forwardly-projecting lens holder portion 51c which faces the rear projecting portion 6m,  
5 with a rib-like elongated protrusion 51f which projects forward from the front end surface 51c1 (see Figures 123, 124 and 127 through 130). As shown in Figure 130, the elongated protrusion 51f is elongated vertically, and is formed to lie in a plane orthogonal to the photographing optical axis Z1 to correspond to the range of rotation  
10 of the rear projecting portion 6m (the contacting surface 6n) about the pivot shaft 33 at the rotation of the second lens frame 6 from the photographing position to the radially retracted position. The rear projecting portion 6m and the rib-like elongated protrusion 51f are  
15 elements of the aforementioned fail-safe structure.

With the fail-safe structure, even if the second lens frame 6 starts retracting to the radially retracted position in a state where the AF lens frame 51 does not retract to the retracted position and stops short of the retracted position accidentally upon the main switch being turned OFF, the contacting surface 6n of the rear projecting portion 6m surely comes into contact with the rib-like elongated protrusion 51f of the AF lens frame  
25 51 first. This prevents the second lens group LG2 from

coming into collision with the AF lens frame 51 to get scratched and damaged thereby even if such a malfunction occurs. In other words, since the moving path of the rear projecting portion 6m does not overlap the third lens group LG3 in the optical axis direction at any angular positions of the second lens frame 6, there is no possibility of any portions of the second lens group 6 other than the rear projecting portion 6m coming into contact with the third lens group LG3 to scratch the third lens group LG3. Accordingly, since the rear projecting portion 6m and the elongated protrusion 51f are only the portions at which the second lens group LG2 and the AF lens frame 51 can contact with each other, the optical performances of the second lens group LG2 and the third lens group LG3 are prevented from deteriorating even if the AF lens frame 51 stops short of the retracted position accidentally upon the main switch being turned OFF. If such a malfunction occurs, it is possible for the second lens frame 6 in the process of moving rearward while rotating to the radially retracted position to push back the AF lens frame 51 forcefully, via the rear projecting portion 6m, which stops short of the retracted position.

Note that although in the illustrated embodiment, the contacting surface 6n and the rib-like elongated protrusion 51f are (possible) contact surfaces, an

alternative embodiment can be applied wherein (possible) contact surfaces of the second lens group frame 6 and the AF lens frame 51 differ from that of the illustrated embodiment. For example, a projection like that of the 5 rear projecting portion 6m can be provided on the AF lens frame 51. Namely, an appropriate position can be provided whereby the above-mentioned projection and another member contact each other before the second lens group LG2 and the third lens group L3 contact any other members.

The contacting surface 6n lies in a plane orthogonal to the photographing optical axis Z1, whereas the front surface of the elongated protrusion 51f is formed as an inclined contacting surface 51g which is inclined to a 15 plane orthogonal to the optical axis of the photographing optical axis Z1 by an angle of NR2 as shown in Figure 128. The inclined contacting surface 51g is inclined toward the rear of the optical axis direction in the direction of movement of the rear projecting portion 6m from a 20 position when the second lens frame 6 is in the photographing position to a position when the second lens frame 6 is in the radially retracted position (upwards as viewed in Figures 128 through 130). Unlike the illustrated embodiment, if the front surface of the 25 elongated protrusion 51f is formed as a mere flat surface

parallel to the contacting surface 6n, the frictional resistance produced between the elongated protrusion 51f and the contacting surface 6n becomes great to impede a smooth movement of the second lens frame 6 in the event 5 that the contacting surface 6n comes into contact with the elongated protrusion 51f when the second lens frame 6 is in the process of moving rearward while rotating to the radially retracted position. In contrast, according to the present embodiment of the fail-safe structure, even 10 if the contacting surface 6n comes into contact with the elongated protrusion 51f when the second lens frame 6 is in the middle of moving rearward while rotating to the radially retracted position, a great frictional resistance is not produced between the elongated 15 protrusion 51f and the contacting surface 6n because of the inclination of the elongated protrusion 51f with respect to the contacting surface 6n. This makes it possible to retract the zoom lens 71 with reliability with less frictional force produced between the elongated 20 protrusion 51f and the contacting surface 6n even if the aforementioned malfunction occurs. In the present embodiment of the fail-safe structure, the angle of inclination NR 2 shown in Figure 128 is set at three degrees as a desirable angle of inclination.

25 It is possible that the elongated protrusion 51f be

formed so that the recessed oblique surface 51h can come into contact with the light shield ring 9, that is fixed to the rear end of the cylindrical lens holder portion 6a, to serve just like the inclined contacting surface 51g of the above illustrated embodiment of the fail-safe structure in the case where the AF lens frame 51 stops short of the retracted position accidentally to a lesser extent than the rear projecting portion 6m comes into contact with the elongated protrusion 51f.

In the retracted position for the second lens frame 6, the position of the optical axis of the second lens group LG2 can be adjusted in directions lying in a plane orthogonal to the photographing optical axis Z1 in such a case where the optical axis of the second lens group LG2 is not precisely coincident with the photographing optical axis Z1 even though the second lens group LG2 is in the photographing position. Such an adjustment is carried out by two positioning devices: a first positioning device for adjusting the positions of the front and rear second lens frame support plates 36 and 37 relative to the second lens group moving frame 8, and a second positioning device for adjusting the point of engagement of the eccentric pin 35b of the rotation limit shaft 35 with the engaging protrusion 6e of the second lens frame 6. The first eccentric shaft 34X and the

second eccentric shaft 34Y are elements of the first positioning device; the positions of the front and rear second lens frame support plates 36 and 37 relative to the second lens group moving frame 8 are adjusted by 5 rotating the first eccentric shaft 34X and the second eccentric shaft 34Y. The rotation limit shaft 35 is a element of the second positioning device; the point of engagement of the eccentric pin 35b with the engaging protrusion 6e is adjusted by rotating the rotation limit 10 shaft 35.

First, the first positioning device for adjusting the positions of the front and rear second lens frame support plates 36 and 37 relative to the second lens group moving frame 8 will be discussed hereinafter. As 15 described above, the front eccentric pin 34X-b of the first eccentric shaft 34X is inserted into the first vertically-elongated hole 36a to be movable and immovable in the first vertically-elongated hole 36a in the lengthwise direction and the widthwise direction thereof, 20 respectively, while the rear eccentric pin 34Y-b of the second eccentric shaft 34Y is inserted into the horizontally-elongated hole 36e to be movable and immovable in the horizontally-elongated hole 36e in the lengthwise direction and the widthwise direction thereof, 25 respectively, as shown in Figures 110, 114 and 115. The

lengthwise direction of the first vertically-elongated hole 36a, which corresponds to the vertical direction of the digital camera 70, is orthogonal to the lengthwise direction of the horizontally-elongated hole 36e, which 5 corresponds to the horizontal direction of the digital camera 70 as shown in Figures 110, 114 and 115. In the following descriptions, the lengthwise direction of the first vertically-elongated hole 36a is referred to as "Y-direction" while the lengthwise direction of the 10 horizontally-elongated hole 36e is referred to as "X-direction".

The lengthwise direction of the first vertically-elongated hole 37a is parallel to the lengthwise direction of the first vertically-elongated hole 36a. Namely, the first vertically-elongated hole 37a is elongated in the Y-direction. The first vertically-elongated hole 36a and the first vertically-elongated hole 37a are formed at opposed positions on the front and rear second lens frame support 15 plates 36 and 37 in the optical axis direction. The lengthwise direction of the horizontally-elongated hole 37e is parallel to the lengthwise direction of the horizontally-elongated hole 36e. Namely, the horizontally-elongated hole 37e is elongated in the 20 x-direction. The horizontally-elongated hole 36e and 25

the horizontally-elongated hole 37e are formed at opposed positions on the front and rear second lens frame support plates 36 and 37 in the optical axis direction. Similar to the front eccentric pin 34X-b, the rear eccentric pin 5 34X-c is movable and immovable in the first vertically-elongated hole 37a in the Y-direction and X-direction, respectively. The front eccentric pin 34Y-b is movable and immovable in the horizontally-elongated hole 37e in the X-direction and Y-direction, 10 respectively.

Similar to the pair of first vertically-elongated holes 36a and 37a and the pair of horizontally-elongated holes 36e and 37e, the lengthwise direction of the second vertically-elongated hole 36f is parallel to the 15 lengthwise direction of the second vertically-elongated hole 37f, while the second vertically-elongated hole 36f and the second vertically-elongated hole 37f are formed at opposed positions on the front and rear second lens frame support plates 36 and 37 in the optical axis 20 direction. The pair of the second vertically-elongated holes 36f and 37f are each elongated in the Y-direction to extend parallel to the pair of first vertically-elongated holes 36a and 37a. The front boss 8j, which 25 is engaged in the second vertically-elongated hole 36f, is movable and immovable in the second vertically-

elongated hole 36f in the Y-direction and X-direction, respectively. Similar to the front boss 8j, the rear boss 8k, which is engaged in the second vertically-elongated hole 37f, is movable and immovable in the second 5 vertically-elongated hole 37f in the Y-direction and X-direction, respectively.

As shown in Figure 113, the large diameter portion 34X-a is inserted into the first eccentric shaft support hole 8f so as not to move in radial directions thereof, 10 and is accordingly rotatable about the axis (adjustment axis PX) of the large diameter portion 34X-a. Likewise, the large diameter portion 34Y-a is inserted into the second eccentric shaft support hole 8i so as not to move in radial directions thereof, and is accordingly 15 rotatable on the axis (adjustment axis PY1) of the large diameter portion 34Y-a.

The front eccentric pin 34Y-b and the rear eccentric pin 34Y-c have the common axis eccentric to the axis of the large diameter portion 34Y-a as mentioned above. 20 Therefore, a rotation of the second eccentric shaft 34Y on the adjustment axis PY1 causes the front and rear eccentric pins 34Y-b and 34b-c to revolve about the adjustment axis PY1, i.e., rotate in a circle about the adjustment axis PY1, thus causing the front eccentric pin 25 34Y-b to push the front second lens frame support plate

36 in the Y-direction while moving in the X-direction and at the same time causing the rear eccentric pin 34Y-c to push the rear second lens frame support plate 37 in the Y-direction while moving in the X-direction. At this 5 time, the front second lens frame support plate 36 moves linearly in the Y-direction while guided in the same direction by the front eccentric pin 34Y-b and the front boss 8j since both the first vertically-elongated hole 36a and the second vertically-elongated hole 36f are 10 elongated in the Y-direction, and at the same time, the rear second lens frame support plate 37 moves linearly in the Y-direction while guided in the same direction by the rear eccentric pin 34Y-c and the rear boss 8k since both the first vertically-elongated hole 37a and the 15 second vertically-elongated hole 37f are elongated in the Y-direction. Consequently, the position of the second lens frame 6 relative to the second lens group moving frame 8 on the front fixing surface 8c thereof varies to adjust the position of the optical axis of the second lens group 20 LG2 in the Y-direction.

The front eccentric pin 34X-b and the rear eccentric pin 34X-c have the common axis eccentric to the axis of the large diameter portion 34X-a as mentioned above. Therefore, a rotation of the first eccentric shaft 34X 25 on the adjustment axis PX causes the front and rear

eccentric pins 34X-b and 34X-c to revolve about the adjustment axis PX, i.e., rotate in a circle about the adjustment axis PX, thus causing the front eccentric pin 34X-b to push the front second lens frame support plate 5 36 in the X-direction while moving in the Y-direction and at the same time causing the rear eccentric pin 34X-c to push the rear second lens frame support plate 37 in the X-direction while moving in the Y-direction. At this time, although the front eccentric pin 34Y-b and the rear 10 eccentric pin 34Y-c are respectively movable in the horizontally-elongated hole 36e and the horizontally- elongated hole 37e in the X-direction, the front second lens frame support plate 36 swings about a fluctuating axis (not shown) extending substantially parallel to the 15 common axis of the front and rear bosses 8j and 8k in the vicinity of this common axis since the second vertically-elongated hole 36f is immovable in the X- direction relative to the front boss 8j and at the same time the rear second lens frame support plate 37 swings 20 about the fluctuating axis since the second vertically-elongated hole 37f is immovable in the X- direction relative to the rear boss 8k. The position of the fluctuating axis corresponds to the following two resultant positions: a front resultant position between 25 the position of the horizontally-elongated hole 36e

relative to the front eccentric pin 34Y-b and the position of the second vertically-elongated hole 36f relative to the front boss 8j, and a rear resultant position between the position of the horizontally-elongated hole 37e 5 relative to the rear eccentric pin 34Y-b and the position of the second vertically-elongated hole 37f relative to the rear boss 8k. Therefore, the fluctuating axis fluctuates in parallel to itself by a swing of the front and rear second lens frame support plates 36 and 37 about the fluctuating axis. A swing of the front and rear second lens frame support plates 36 and 37 about the fluctuating axis causes the pivot shaft 33 to move substantially linearly in the X-direction. Therefore, the second lens group LG2 moves in the X-direction by a 10 rotation of the first eccentric shaft 34X on the adjustment axis PX.

15

Figure 116 shows another embodiment of the first positioning device for adjusting the positions of the front and rear second lens frame support plates 36 and 37 relative to the second lens group moving frame 8. This embodiment of the first positioning device is different from the above described first positioning device in that a front obliquely-elongated hole 36f' and a rear obliquely-elongated hole 37f' in which the front boss 8j 20 and the rear boss 8k are engaged are formed on the front 25

and rear second lens frame support plates 36 and 37 instead of the second vertically-elongated hole 36f and the second vertically-elongated hole 37f, respectively. The front obliquely-elongated hole 36f' and the rear obliquely-  
5 elongated hole 37f' extend parallel to each other obliquely to both X-direction and Y-direction, and are aligned in the optical axis direction. Since each of the front obliquely-elongated hole 36f' and the rear obliquely-elongated hole 37f' includes both a component in the X-direction and a component in the Y-direction,  
10 a rotation of the second eccentric shaft 34Y on the adjustment axis PY1 causes the front obliquely-elongated hole 36f' and the rear obliquely-elongated hole 37f' to move in the Y-direction while moving in the X-direction  
15 slightly relative to the front boss 8j and the rear boss 8k, respectively. Consequently, the front and rear second lens frame support plates 36 and 37 move in the Y-direction while the respective lower end portions thereof swing slightly in the X-direction. On the other hand,  
20 a rotation of the first eccentric shaft 34X on the adjustment axis PX causes the front and rear second lens frame support plates 36 and 37 to move in the X-direction while moving (swinging) slightly in the Y-direction. Accordingly, the position of the optical axis of the  
25 second lens group LG2 can be adjusted in directions lying

in a plane orthogonal to the photographing optical axis Z1 by a combination of an operation of the first eccentric shaft 34X and an operation of the second eccentric shaft 34Y.

- 5       The set screw 66 needs to be loosened before the position of the optical axis of the second lens group LG2 is adjusted by operating the first eccentric shaft 34X and the second eccentric shaft 34Y. The set screw 66 is tightened after the adjustment operation is completed.
- 10      Thereafter, the front and rear second lens frame support plates 36 and 37 are tightly fixed to the front fixing surface 8c and the rear fixing surface 8e to be held at their respective adjusted positions. Therefore, the pivot shaft 33 is also held at its adjusted position.
- 15      Consequently, the position of the optical axis of the second lens group LG2 is held at its adjusted position since the position of the optical axis of the second lens group LG2 depends on the position of the pivot shaft 33. As a result of the optical axis position adjustment operation, the set screw 66 has been moved radially from the previous position thereof; however, this presents no problem because the set screw 66 does not move radially to such an extent so as to interfere with the second lens group moving frame 8 by the optical axis position
- 20      adjustment operation since the threaded shaft portion 66a
- 25

is loosely fitted in the screw insertion hole 8h as shown in Figure 113.

A two-dimensional positioning device which incorporates a first movable stage movable linearly along 5 a first direction and a second movable stage movable linearly along a second direction perpendicular to the first direction, wherein an object the position of which is to be adjusted is mounted on the second movable stage, is known in the art. The structure of this conventional 10 two-dimensional positioning device is generally complicated. In contrast, the above illustrated first positioning device for adjusting the positions of the front and rear second lens frame support plates 36 and 37 relative to the second lens group moving frame 8 is 15 simple because each of the front second lens frame support plate 36 and the rear second lens frame support plate 37 is supported on a corresponding single flat surface (the front fixing surface 8c or the rear fixing surface 8e) to be movable thereon in both X-direction and Y-direction, 20 which makes it possible to achieve a simple two-dimensional positioning device.

Although the above illustrated first positioning device includes two support plates (the pair of second lens frame support plates 36 and 37) for supporting the 25 second lens frame 6, which are positioned separately from

each other in the optical axis direction to increase a stability of the structure supporting the second lens frame 6, it is possible for the second lens frame 6 to be supported with only one of the two support plates. In 5 this case, the first positioning device has only to be provided on the one support plate.

Nevertheless, in the above illustrated embodiment of the first positioning device, the front second lens frame support plate 36 and the rear second lens frame 10 support plate 37 are arranged on front and rear sides of the second lens group moving frame 8, each of the first and second eccentric shafts 34X is provided at the front and rear ends thereof with a pair of eccentric pins (34X-b and 34X-c), respectively, and the second lens group moving 15 frame 8 is provided on front and rear sides thereof with a pair of bosses (8j and 8k), respectively. With this arrangement, a rotation of either eccentric shafts 34X or 34Y causes the pair of second lens frame support plates 36 and 37 to move in parallel as one-piece member. 20 Specifically, rotating the first eccentric shaft 34X with a screwdriver engaged in the recess 34X-d causes the front and rear eccentric pins 34X-b and 34X-c to rotate together by the same amount of rotation in the same rotational direction, thus causing the pair of second lens frame 25 support plates 36 and 37 to move in parallel as an integral

member in the X-direction. Likewise, rotating the second eccentric shaft 34Y with a screwdriver engaged in the recess 34Y-d causes the front and rear eccentric pins 34Y-b and 34Y-c to rotate together by the same amount of 5 rotation in the same rotational direction, thus causing the pair of second lens frame support plates 36 and 37 to move in parallel as an integral member in the Y-direction. When the first and second eccentric shafts 34X and 34Y are each rotated with a screwdriver engaged 10 in the recesses 34X-d and 34Y-d, respectively, the rear second lens frame support plate 37 properly follows the movement of the front second lens frame support plate 36 without being warped. Accordingly, the optical axis of 15 the second lens group LG2 does not tilt by an operation of the first positioning device, which makes it possible to adjust the position of the optical axis of the second lens group LG2 two-dimensionally in directions lying in a plane orthogonal to the photographing optical axis Z1 with a high degree of precision.

20 Since the first and second eccentric shafts 34X and 34Y are supported and held between the front second lens frame support plate 36 and the rear second lens frame support plate 37 disposed on front and rear sides of the shutter unit 76, each of the first and second eccentric 25 shafts 34X and 34Y is elongated so that the length thereof

becomes close to the length of the second lens group moving frame 8 in the optical axis direction, just as the length of the pivot shaft 33. This prevents the second lens group moving frame 8 from tilting, which accordingly makes 5 it possible to adjust the position of the optical axis of the second lens group LG2 two-dimensionally in directions lying in a plane orthogonal to the photographing optical axis Z1 with a higher degree of precision.

10       The second positioning device for adjusting the point of engagement of the eccentric pin 35b of the rotation limit shaft 35 with the engaging protrusion 6e of the second lens frame 6 will be hereinafter discussed. As shown in Figures 111 and 112, the large diameter portion 15 35a of the rotation limit shaft 35 is rotatably fitted in the through hole 8m with the eccentric pin 35b projecting rearward from the rear end of the through hole 8m. Note that the large diameter portion 35a of the rotation limit shaft 35 does not rotate by itself with 20 respect to the through hole 8m, however, if a predetermined amount of force is applied, it is possible for the large diameter portion 35a to be rotated.

As shown in Figure 109, the eccentric pin 35b is positioned at one end of the moving path of the tip of 25 the engaging protrusion 6e of the second lens frame 6.

The eccentric pin 35b projects rearward from the rear end of the large diameter portion 35a so that the axis of the eccentric pin 35b is eccentric from the axis of the large diameter portion 35a as shown in Figure 117. Therefore,  
5 a rotation of the eccentric pin 35b on an axis thereof (adjustment axis PY2) causes the eccentric pin 35b to revolve about the adjustment axis PY2, thus causing the eccentric pin 35b to move in the Y-direction. Since the eccentric pin 35b of the rotation limit shaft 35 serves  
10 as an element for determining the photographing position of the second lens frame 6, a displacement of the eccentric pin 35b in the Y-direction causes the second lens group LG2 to move in the Y-direction. Therefore, the position of the optical axis of the second lens group LG2 can be  
15 adjusted in the Y-direction by an operation of the rotation limit shaft 35. Accordingly, the position of the optical axis of the second lens group LG2 can be adjusted in the Y-direction by the combined use of the rotation limit shaft 35 and the second eccentric shaft  
20 34Y. It is desirable that the rotation limit shaft 35 be operated secondarily in a particular case where the range of adjustment of the second eccentric shaft 34Y is insufficient.

As shown in Figure 110, the recess 34X-d of the first  
25 eccentric shaft 34X, the recess 34Y-d of the second

eccentric shaft 34Y and the recess 35c of the rotation limit shaft 35 are all exposed to the front of the second lens group moving frame 8. In addition, the head of the set screw 66 that is provided with the cross slot 66b is 5 exposed to the front of the second lens group moving frame 8. Due to this structure, the position of the optical axis of the second lens group LG2 can be adjusted two-dimensionally with the above described first and second positioning devices from the front of the second 10 lens group moving frame 8, i.e., all the operating members of the first and second positioning devices are accessible from the front of the second lens group moving frame 8. On the other hand, the first external barrel 12, that is positioned radially outside the second lens group moving 15 frame 8, is provided on an inner peripheral surface thereof with the inner flange 12c which projects radially inwards to close the front of the second lens group moving frame 8 in cooperation with the fixing ring 3.

As shown in Figures 131 and 132, the first external 20 barrel 12 is provided on the inner flange 12c with four screwdriver insertion holes 12g1, 12g2, 12g3 and 12g4 which penetrate the inner flange 12c in the optical axis direction so that the recess 34X-d, the recess 34Y-d, the recess 35c and the cross slot 66b are exposed to the front 25 of the first external barrel 12, respectively. A

screwdriver can be brought into engagement with the recess 34X-d, the recess 34Y-d, the recess 35c and the cross slot 66b from the front of the second lens group moving frame 8 through the four screwdriver insertion holes 12g1, 12g2, 5 12g3 and 12g4, respectively, without removing the first external barrel 12 from the front of the second lens group moving frame 8. As shown in Figures 2, 131 and 132, portions of the fixing ring 3 which are aligned with the screwdriver insertion holes 12g2, 12g3 and 12g4 are cut 10 out so as not to interfere with the screwdriver. The respective front ends of the four screwdriver insertion holes 12g1, 12g2, 12g3 and 12g4 are exposed to the front of the zoom lens 71 by removing the lens barrier cover 101 and the aforementioned lens barrier mechanism 15 positioned immediately behind the lens barrier cover 101. Due to this structure, the position of the optical axis of the second lens group LG2 can be adjusted two-dimensionally with the above described first and second positioning devices from the front of the second lens 20 group moving frame 8 without dismounting components of the zoom lens 71 except for substantially the lens barrier mechanism, i.e., in substantially finished form. Accordingly, the position of the optical axis of the second lens group LG2 can be easily adjusted two- 25 dimensionally with the first and second positioning

devices in a final assembling process even if the degree of deviation of the second lens group LG2 is out of tolerance during assembly. This results in an improvement in workability of the assembly process.

5       The structure accommodating the second lens group LG2 and other optical elements behind the second lens group LG2 in the camera body 72 upon the main switch of the digital camera 70 being turned OFF has mainly been discussed above. Improvements in the structure of the  
10 zoom lens 71 which accommodates the first lens group LG1 upon the main switch of the digital camera 70 being turned OFF will be hereinafter discussed in detail.

As shown in Figure 2, the inner flange 12c of the first external barrel 12 is provided at radially opposite  
15 positions thereon with respect to the photographing optical axis Z1 with a pair of first guide grooves 12b, respectively, while the first lens group adjustment ring 2 is provided on an outer peripheral surface thereof with a corresponding pair of guide projections 2b which project  
20 radially outwards in opposite directions away from each other to be slidably fitted in the pair of first guide grooves 12b, respectively. Only one guide projection 2b and the associated first guide groove 12b appear in Figures 9, 141 and 142. The pair of first guide grooves  
25 12b extend parallel to the photographing optical axis Z1

so that the combination of the first lens frame 1 and the first lens group adjustment ring 2 is movable in the optical axis direction with respect to the first external barrel 12 by engagement of the pair of guide projections 5 2b with the pair of first guide grooves 12b.

The fixing ring 3 is fixed to the first external barrel 12 by the two set screws 64 to close the front of the pair of guide projections 2b. The fixing ring 3 is provided at radially opposite positions thereon with 10 respect to the photographing optical axis Z1 with a pair of spring receiving portions 3a, so that a pair of compression coil springs 24 are installed in a compressed manner between the pair of spring receiving portions 3a and the pair of guide projections 2b, respectively. 15 Therefore, the first lens group adjustment ring 2 is biased rearward in the optical axis direction with respect to the first external barrel 12 by the spring force of the pair of compression coil springs 24.

In an assembly process of the digital camera 70, the 20 position of the first lens frame 1 relative to the first lens group adjustment ring 2 in the optical axis direction can be adjusted by changing the position of engagement of the male screw thread 1a relative to the female screw thread 2a of the first lens group adjustment ring 2. This 25 adjusting operation can be carried out in a state where

the zoom lens 71 is set at the ready-to-photograph state as shown in Figure 141. Two-dot chain lines shown in Figure 141 show movements of the first lens frame 1 together with the first lens group LG1 with respect to 5 the first external barrel 12 in the optical axis direction. On the other hand, when the zoom lens 71 is retracted to the retracted position as shown in Figure 10, the first external barrel 12, together with the fixing ring 3, can further move rearward relative to the first lens frame 10 1 and the first lens group adjustment ring 2 while compressing the pair of compression coil springs 24 even after the first lens frame 1 has fully retracted to a point at which the first lens frame 1 contacts with a front surface of the shutter unit 76 to thereby be prevented 15 from further moving rearward (see Figure 142). Namely, when the zoom lens 71 is retracted to the retracted position, the first external barrel 12 is retracted to be accommodated in such a manner as to reduce an axial margin (axial space) for positional adjustment of the 20 first lens frame 1 in the optical axis direction. This structure makes it possible for the zoom lens 71 to be fully retracted deeper into the camera body 72. Conventional telescoping lens barrels in which a lens frame (which corresponds to the first lens frame 1) is 25 directly fixed to an external lens barrel (which

corresponds to the first external barrel 12) by screw threads (similar to the female screw thread 2a and the male screw thread 1a) without any intermediate member (which corresponds to the first lens group adjustment ring 2) interposed between the lens frame and the external lens barrel are known in the art. In this type of telescoping lens barrels, since the amount of retracting movement of the external lens barrel into a camera body is the same as that of the lens frame, the external lens barrel cannot 10 be further moved rearward relative to the lens frame, unlike the first external barrel 12 of the present embodiment of the zoom lens.

The first lens frame 1 is provided at the rear end thereof with an annular end protrusion 1b (see Figures 15 133, 134, 141 and 142), the rear end of which is positioned behind the rearmost point on the rear surface of the first lens group LG1 in the optical axis direction, so that the rear end of the annular end protrusion 1b comes into contact with a front surface of the shutter unit 76 to 20 prevent the rear surface of the first lens group LG1 from contacting with the shutter unit 76 and being damaged thereby when the zoom lens 71 is retracted to the retracted position.

More than two guide projections, each corresponding 25 to each of the two guide projections 2b, can be formed

on the first lens group adjustment ring 2 at any positions on an outer peripheral surface thereof, and also the shape of each guide projection is optional. According to the number of the guide projections of the first lens group 5 adjustment ring 2, the fixing ring 3 can be provided with more than two spring receiving portions each corresponding to each of the two spring receiving portions 3a, and also the shape of each spring receiving portion is optional. In addition, the pair of spring receiving 10 portions 3a is not essential; the pair of compression coil springs 24 can be installed in a compressed manner between corresponding two areas on a rear surface of the fixing ring 3 and the pair of guide projections 2b, respectively.

The first lens group adjustment ring 2 is provided 15 on an outer peripheral surface thereof, at the front end of the outer peripheral surface at substantially equi-angular intervals about the photographing optical axis Z1, with a set of four engaging projections 2c (see Figure 2) which are engageable with a front surface 3c of the fixing ring 3. The rear limit for the axial movement of the first lens group adjustment ring 2 with respect to the fixing ring 3 (i.e., with respect to the first external barrel 12) is determined by engagement 20 (bayonet engagement) of the set of four engaging projections 2c with the front surface 3c of the fixing 25

ring 3 (see Figures 9 and 141). The set of four engaging projections 2c serve as a set of bayonets.

Specifically, the fixing ring 3 is provided on an inner edge thereof with a set of four recesses 3b (see 5 Figure 2) to correspond to the set of four engaging projections 2c, respectively. The set of four engaging projections 2c can be inserted into the set of four recesses 3b from behind, respectively, and are engaged with the front surface 3c of the fixing ring 3 by rotating 10 one of the first lens group adjustment ring 2 and the fixing ring 3 relative to the other clockwise or counterclockwise after the set of four engaging projections 2c are inserted into the set of four recesses 3b from behind. After this operation rotating one of the 15 first lens group adjustment ring 2 and the fixing ring 3 relative to the other, a rear end surface 2c1 of each engaging projection 2c is pressed against the front surface 3c (a surface of the fixing ring 3 which can be seen in Figure 2) of the fixing ring 3 by the spring force 20 of the pair of compression coil springs 24. This firm engagement of the set of four engaging projections 2c with the front surface 3c of the fixing ring 3 prevents the combination of the first lens frame 1 and the first lens group adjustment ring 2 from coming off the first external 25 barrel 12 from the rear thereof, and accordingly

determines the rear limit for the axial movement of the first lens group adjustment ring 2 with respect to the first external barrel 12.

When the zoom lens 71 is fully retracted into the camera body 72 as shown in Figures 10 and 142, the rear surfaces 2c1 of the set of four engaging projections 2c are disengaged from the front surface 3c of the fixing ring 3 because the first lens group adjustment ring 2 has moved forward slightly with respect to the first external barrel 12 from the position of the first lens group adjustment ring 2 shown in Figure 141 by further compressing the pair of compression coil springs 24. However, once the zoom lens 71 enters the ready-to-photograph state as shown in Figure 141, the rear surfaces 2c1 are re-engaged with the front surface 3c. Accordingly, the rear surfaces 2c1 of the four engaging projections 2c and the front surface 3c serve as reference surfaces for determining the position of the first lens group LG1 with respect to the first external barrel 12 in the optical axis direction in the ready-to-photograph state of the zoom lens barrel 71. With this structure, even if the axial position of the first lens group LG1 with respect to the first external barrel 12 changes when the zoom lens 71 is retracted into the camera body 72, the first lens group LG1 automatically returns to its

original position by the action of the pair of compression coil springs 24 as soon as the zoom lens 71 is ready to photograph.

At least two and any number other than four engaging 5 projections each corresponding to each of the four engaging projections 2c can be formed on the first lens group adjustment ring 2 at any position on an outer peripheral surface thereof. According to the number of the engaging projections of the first lens group 10 adjustment ring 2, the fixing ring 3 can be provided with at least two and any number other than four recesses each corresponding to each of the four recesses 3b. Moreover, the shape of each engaging projection of the first lens group adjustment ring 2 and also the shape of each spring 15 receiving portion of the fixing ring 3 are optional as long as each engaging projection of the first lens group adjustment ring 2 is insertable into the corresponding recess of the fixing ring 3.

As has been described above, when the zoom lens 71 20 changes from the ready-to-photograph state to the retracted state, the cylindrical lens holder portion 6a of the second lens frame 6, which holds the second lens group LG2, rotates about the pivot pin 33 in a direction away from the photographing optical axis z1 inside the 25 second lens group moving frame 8, while the AF lens frame

51 which holds the third lens group LG3 enters the space in the second lens group moving frame 8 from which the lens holder portion 6a has retracted (see Figures 134, 136 and 137). In addition, when the zoom lens 71 changes 5 from the ready-to-photograph state to the retracted state, the first lens frame 1 that holds the first lens group LG1 enters the second lens group moving frame 8 from the front thereof (see Figures 133 and 135). Accordingly, the second lens group moving frame 8 has to be provided 10 with two internal spaces: a front internal space immediately in front of the central inner flange 8s in which the first lens frame 1 is allowed to move in the optical axis direction, and a rear internal space immediately behind the central inner flange 8s in which 15 the second lens frame 6 is allowed to retract along a plane orthogonal to the photographing optical axis Z1 and in which the AF lens frame 51 is allowed to move in the optical axis direction. In the present embodiment of the zoom lens, the shutter unit 76, specifically an actuator 20 thereon, is disposed inside the second lens group moving frame 8, which accommodates more than one lens group therein, in a space-saving manner to maximize the internal space of the second lens group moving frame 8.

Figure 140 shows the elements of the shutter unit 25 76. The shutter unit 76 is provided with a base plate

120 having a central circular aperture 120a with its center on the photographing optical axis z1. The base plate 120 is provided on a front surface thereof (a surface which can be seen in Figure 140) above the circular aperture 120a with a shutter-actuator support portion 120b formed integral with the base plate 120. The shutter-actuator support portion 120b is provided with a substantially cylindrical accommodation recess 120b1 in which the shutter actuator 131 is accommodated. After 10 the shutter actuator 131 is embedded in the accommodation recess 120b1, a holding plate 121 is fixed to the shutter-actuator support portion 120b so that the shutter actuator 131 is supported by the base plate 120 on the front thereof.

15       The shutter unit 76 is provided with a diaphragm-actuator support member 120c which is fixed to the back of the base plate 120 on the right side of the cylindrical recess 120b1 as viewed from the rear of the base plate 120. The shutter unit 76 is provided with a 20 diaphragm-actuator support cover 122 having a substantially cylindrical accommodation recess 122a in which the diaphragm actuator 132 is accommodated. The diaphragm-actuator support cover 122 is fixed to the back of the diaphragm-actuator support member 120c. After the 25 diaphragm actuator 132 is embedded in the accommodation

recess 122a, the diaphragm-actuator support cover 122 is fixed to the back of the diaphragm-actuator support member 120c so that the diaphragm actuator 132 is supported by the diaphragm-actuator support member 120c on the back thereof. The shutter unit 76 is provided with a covering 123 which is fixed to the diaphragm-actuator support cover 122 to cover an outer peripheral surface thereof.

The holding plate 121 is fixed to the shutter-actuator support portion 120b by a set screw 129a. The diaphragm-actuator support member 120c is fixed to the back of the base plate 120 by set screw 129b. Furthermore, the diaphragm-actuator support member 120c is fixed to the holding plate 121 by a set screw 129c. A lower end portion of the diaphragm-actuator support member 120c which is provided with a screw hole into which the set screw 129b is screwed is formed as a rearward-projecting portion 120cl.

The shutter S and the adjustable diaphragm A are mounted to the rear of the base plate 120 immediately beside the diaphragm-actuator support member 120c. The shutter S is provided with a pair of shutter blades S1 and S2, and the adjustable diaphragm A is provided with a pair of diaphragm blades A1 and A2. The pair of shutter blades S1 and S2 are pivoted on a first pair of pins (not shown) projecting rearward from the back of the base plate

120, respectively, and the pair of diaphragm blades A1  
and A2 are pivoted on a second pair of pins (not shown)  
projecting rearward from the back of the base plate 120,  
respectively. These first and second pairs of pins do  
5 no appear in Figure 140. The shutter unit 76 is provided  
between the shutter S and the adjustable diaphragm A with  
a partition plate 125 which prevents the shutter S and  
the adjustable diaphragm A from interfering with each  
other. The shutter S, the partition plate 125 and the  
10 adjustable diaphragm A are fixed to the back of the base  
plate 120 in this order from front to rear in the optical  
axis direction, and thereafter a blade-holding plate 126  
is fixed to the back of the base plate 120 to hold the  
shutter S, the partition plate 125 and the adjustable  
15 diaphragm A between the base plate 120 and the blade-  
holding plate 126. The partition plate 125 and the  
blade-holding plate 126 are provided with a circular  
aperture 125a and a circular aperture 126a, respectively,  
through which rays of light of an object image which is  
20 to be photographed pass to be incident on the CCD image  
sensor 60 through the third lens group LG3 and the low-pass  
filter LG4. The circular apertures 125a and 126a are  
aligned with the central circular aperture 120a of the  
base plate 120.

25 The shutter actuator 131 is provided with a rotor

131a, a rotor magnet (permanent magnet) 131b, a stator 131c made of steel, and a bobbin 131d. The rotor 131a is provided with a radial arm portion, and an eccentric pin 131e which projects rearwards from the tip of the 5 radial arm portion to be inserted into cam grooves S1a and S2a of the pair of shutter blades S1 and S2. Strands (not shown) through which electric current is passed via the flexible PWB 77 to control rotation of the rotor 131a are wound on the bobbin 131d. Passing a current through 10 the strands wound on the bobbin 131d causes the rotor 131a to rotate forward or reverse depending on the magnetic field which varies in accordance with the direction of the passage of the current. Rotations of the rotor 131a forward and reverse cause the eccentric pin 131e to swing 15 in forward and reverse directions, thus causing the pair of shutter blades S1 and S2 to open and close, respectively, by engagement of the eccentric pin 131e with the cam grooves S1a and S2a.

The diaphragm actuator 132 is provided with a rotor 20 132a and a rotor magnet (permanent magnet) 132b. The rotor 132a is provided with a radial arm portion having two ninety-degree bends, and an eccentric pin 132c which projects rearwards from the tip of the radial arm portion to be inserted into cam grooves A1a and A2a of the pair 25 of diaphragm blades A1 and A2. Strands (not shown)

through which electric current is passed via the flexible PWB 77 to control rotation of the rotor 132a are wound on the diaphragm-actuator support member 120c and the diaphragm-actuator support cover 122. Passing a current 5 through the strands wound on the diaphragm-actuator support member 120c and the diaphragm-actuator support cover 122 causes the rotor 132a to rotate forward or reverse depending on the magnetic field which varies in accordance with the direction of the passage of the 10 current. Rotations of the rotor 132a forward and reverse cause the eccentric pin 132c to swing in forward and reverse directions, thus causing the pair of diaphragm blades A1 and A2 to open and close, respectively, by engagement of the eccentric pin 132c with the cam grooves A1a and A2a.

15       The shutter unit 76 is prepared as a subassembly in advance, and fitted into the second lens group moving frame 8 to be fixed thereto. As shown in Figures 108 and 110, the shutter unit 76 is supported by the second lens group moving frame 8 therein so that the base plate 120 is positioned immediately in front of the central inner flange 8s. A terminal end 77e of the flexible PWB 77 is 20 fixed to a front surface of the holding plate 121 (see Figures 108, 110, 133 and 135).

25       The second lens group moving frame 8 has a cylindrical shape coaxial to other rotatable rings such

as the cam ring 11. The axis of the second lens group moving frame 8 coincides with the lens barrel axis Z0 of the zoom lens 71. The photographing optical axis Z1 is eccentric downward from the lens barrel axis Z0 to secure 5 some space in the second lens group moving frame 8 into which the second lens group LG2 is retracted to the radially-retracted position (see Figures 110 through 112). On the other hand, the first lens frame 1, which supports the first lens group LG1, is in the shape of a 10 cylinder with its center on the photographing optical axis Z1, and is guided along the photographing optical axis Z1. Due to this structure, the space in the second lens group moving frame 8 which is occupied by the first lens group LG1 is secured in the second lens group moving frame 15 8 below the lens barrel axis Z0. Accordingly, sufficient space (upper front space) is easily secured in the second lens group moving frame 8 in front of the central inner flange 8s on the opposite side of the lens barrel axis Z0 from the photographing optical axis Z1 (i.e., above 20 the lens barrel axis Z0) so that the shutter actuator 131 and supporting members therefor (the shutter-actuator support portion 120b and the holding plate 121) are positioned in the upper front space along an inner peripheral surface of the second lens group moving frame 25 8. With this structure, the first lens frame 1 does not

interfere with either the shutter actuator 131 or the holding plate 121 even if the first lens frame 1 enters the second lens group moving frame 8 from the front thereof as shown in Figure 135. Specifically, in the retracted 5 state of the zoom lens 71, the holding plate 121 and the shutter actuator 131, which is positioned behind the holding plate 121, are positioned in an axial range in which the first lens group LG1 is positioned in the optical axis direction; namely, the holding plate 121 and the 10 shutter actuator 131 are positioned radially outside the first lens group LG1. This maximizes the utilization of the internal space of the second lens group moving frame 8, thus contributing to a further reduction of the length of the zoom lens 71.

15       The first lens frame 1 that holds the first lens group LG1 is positioned in the first external barrel 12 to be supported thereby via the first lens group adjustment ring 2 as shown in Figure 138 to be movable together with the first external barrel 12 in the optical 20 axis direction though the first lens group adjustment ring 2 is not shown in Figures 133 and 135 around the first lens frame 1 for the purpose of illustration. The inner flange 12c of the first external barrel 12 is provided, above the portion thereof which holds the first lens frame 25 1 and the first lens group adjustment ring 2, with a

through hole 12c1 which has a substantially arm shape as viewed from or rear of the first external barrel 12 and which penetrates the first external barrel 12 in the optical axis direction. The through hole 12c1 is shaped 5 so that the holding plate 121 can enter the through hole 12c1 from behind. The holding plate 121 enters the through hole 12c1 as shown in Figure 138 when the zoom lens 71 is in the retracted position.

In the rear internal space of the second lens group 10 moving frame 8 behind the central inner flange 8s, not only the forwardly-projecting lens holder portion 51c (the third lens group LG3) of the AF lens frame 51 moves in and out in the optical axis direction above the photographing optical axis Z1 that is positioned below 15 the lens barrel axis Z0, but also the cylindrical lens holder portion 6a retracts into the space on the opposite side of the lens barrel axis Z0 from the photographing optical axis Z1 when the zoom lens 71 is retracted into the camera body 72. Accordingly, there is substantially 20 no extra space in the second lens group moving frame 8 behind the central inner flange 8s in a direction (vertical direction) of a straight line M1 orthogonally intersecting both the lens barrel axis Z0 and the photographing optical axis Z1 (see Figure 112). Whereas, 25 two side spaces not interfering with either the second

lens group LG2 or the third lens group LG3 are successfully secured on respective sides (right and left sides) of the line M1 in the second lens group moving frame 8 until an inner peripheral surface thereof behind the central inner  
5 flange 8s in a direction (see Figure 112) of a straight line M2 which is orthogonal to the straight line M1 and intersecting the photographing optical axis Z1. As can be seen in Figures 111 and 112, the left side space of the two side spaces which is positioned on the left side  
10 as viewed in Figure 112 (on the left side of the lens barrel axis Z0 and the photographing optical axis Z1 as viewed from the rear of the second lens frame 8) is utilized partly as the space for the swing arm portion 6c of the swingable second lens frame 6 to swing therein and partly  
15 as the space for accommodating the above described first positioning device, with which the positions of the front and rear second lens frame support plates 36 and 37 relative to the second lens group moving frame 8 can be adjusted. The right side space of the aforementioned two  
20 side spaces which is positioned on the right side as viewed in Figure 112 is utilized as the space for accommodating the diaphragm actuator 132 and supporting members therefor (the diaphragm-actuator support cover 122 and the cover ring 123) so that the diaphragm actuator 132  
25 and the supporting members are positioned along an inner

peripheral surface of the second lens group moving frame 8. More specifically, the diaphragm actuator 132 and the supporting members (the diaphragm-actuator support cover 122 and the cover ring 123) lie on the straight line M2. Accordingly, as can be understood from Figures 111, 112 and 137, the diaphragm actuator 132, the diaphragm-actuator support cover 122 and the cover ring 123 do not interfere with either the range of movement of the second lens group LG2 or the range of movement of the third lens group LG3.

Specifically, in the inside of the second lens group moving frame 8 behind the central inner flange 8s, the second lens group LG2 (the cylindrical lens holder portion 6a) and the third lens group LG3 (forwardly-projecting lens holder portion 51c) are accommodated on upper and lower sides of the lens barrel axis Z0, respectively, while the above described first positioning device and diaphragm actuator 132 are positioned on right and left sides of the lens barrel axis Z0 when the zoom lens 71 is in the retracted state. This maximizes the utilization of the internal space of the second lens group moving frame 8 in the retracted state of the zoom lens 71. In this state, the diaphragm-actuator support cover 122, the cover ring 123 and the diaphragm actuator 132 are positioned in the space radially outside the space

in which the second lens group LG2 and the third lens group LG3 are accommodated. This contributes to a further reduction of the length of the zoom lens 71.

In the present embodiment of the zoom lens, the base 5 plate 120 of the shutter unit 120 is positioned in front of the central inner flange 8s, whereas the diaphragm actuator 132, the diaphragm-actuator support cover 122 and the cover ring 123 are positioned behind the central inner flange 8s. In order to allow the diaphragm actuator 10 132, the diaphragm-actuator support cover 122 and the cover ring 123 extend behind the central inner flange 8s, the central inner flange 8s is provided with a substantially circular through hole 8s1 in which the cover ring 123 is fitted (see Figures 110 through 112). The 15 central inner flange 8s is further provided below the through hole 8s1 with an accommodation recess 8s2 in which the rearward-projecting portion 120c1 of the diaphragm-actuator support member 120c is accommodated.

The forwardly-projecting lens holder portion 51c of 20 the AF lens frame 51 is provided, on the side surface 51c4 among the four side surfaces 51c3, 51c4, 51c5 and 51c6 around the forwardly-projecting lens holder portion 51c, with a recess 51i which is formed by cutting out a part of the forwardly-projecting lens holder portion 51c. The 25 recess 51i is formed to correspond to the shapes of outer

peripheral surfaces of the ring cover 123 and the accommodation recess 8s2 of the second lens group moving frame 8 so that the forwardly-projecting lens holder portion 51c does not interfere with the ring cover 123 and the accommodation recess 8s2 in the retracted state of the zoom lens 71. Namely, the outer peripheral portions of the ring cover 123 and the accommodation recess 8s2 partly enter the recess 51i when the zoom lens 71 is fully retracted into the camera body 72 (see Figures 122, 130 and 137). This further maximizes the utilization of the internal space of the second lens group moving frame 8 to minimize the length of the zoom lens 71.

In the present embodiment of the zoom lens, even the shutter actuator 131 and the diaphragm actuator 132 are structured in consideration of the utilization of the internal space of the zoom lens 71.

The space in front of the base plate 120 is narrow in the optical axis direction since the shutter unit 76 is supported by the second lens group moving frame 8 therein toward the front thereof as can be seen in Figures 9 and 10. Due to the limitation of the space in front of the base plate 120, the shutter actuator 131 adopts the structure, in which the rotor magnet 131b and the bobbin 131d do not adjoin each other in the optical axis

direction but are positioned separately from each other in a direction perpendicular to the optical axis direction, so that variations of the magnetic field generated on the side of the bobbin 131d are transferred to the side of 5 the rotor magnet 131d via the stator 131c. This structure reduces the thickness of the shutter actuator 131 in the optical axis direction, thus making it possible for the shutter actuator 131 to be positioned in the limited space in front of the base plate 120 without problems.

10 On the other hand, the space behind the base plate 120 is also limited in a direction perpendicular to the optical axis direction because the second lens group LG2 and other retractable parts are positioned behind the base plate 120. Due to the limitation of the space behind the 15 base plate 120, the diaphragm actuator 132 adopts the structure in which strands are wound directly on the diaphragm-actuator support member 120c and the diaphragm-actuator support cover 122 which cover the rotor magnet 132b. This structure reduces the height of 20 the diaphragm actuator 132 in a direction perpendicular to the optical axis direction, thus making it possible for the diaphragm actuator 132 to be positioned in the limited space behind the base plate 120 without problems.

The digital camera 70 is provided above the zoom lens 25 71 with a zoom viewfinder, the focal length of which varies

to correspond to the focal length of the zoom lens 71. As shown in Figures 9, 10 and 143, the zoom viewfinder is provided with a zoom type viewing optical system including an objective window plate 81a (not shown in 5 Figure 143), a first movable power-varying lens 81b, a second movable power-varying lens 81c, a mirror 81d, a fixed lens 81e, a prism (erecting system) 81f, an eyepiece 81g and an eyepiece window plate 81h, in that order from the object side along a viewfinder optical axis. The 10 objective window plate 81a and the eyepiece window plate 81h are fixed to the camera body 72, and the remaining optical elements (81b through 81g) are supported by a viewfinder support frame 82. Among the optical elements 81b through 81g supported by the viewfinder support frame 15 82, the mirror 81d, the fixed lens 81e, the prism 81f and the eyepiece 81g are fixed to the viewfinder support frame 82 at their respective predetermined positions thereon. The zoom viewfinder is provided with a first movable frame 83 and a second movable frame 84 which hold the first 20 movable power-varying lens 81b and the second movable power-varying lens 81c, respectively. The first movable frame 83 and the second movable frame 84 are guided in the optical axis direction by a first guide shaft 85 and a second guide shaft 86 which extend in a direction 25 parallel to the photographing optical axis Z1,

respectively. The first movable power-varying lens 81b and the second movable power-varying lens 81c have a common optical axis z3 which remains in parallel to the photographing optical axis z1 regardless of variations  
5 of the relative position between the first movable power-varying lens 81b and the second movable power-varying lens 81c. The first movable frame 83 and the second movable frame 84 are biased forward, toward the objective side, by a first compression coil spring 87 and  
10 a second compression coil spring 88, respectively. The zoom viewfinder is provided with a cam-incorporated gear 90 having a substantially cylindrical shape. The cam-incorporated gear 90 is fitted on a rotational shaft 89 to be supported thereon. The rotational shaft 89 is  
15 fixed to the viewfinder support frame 82 to extend parallel to the optical axis z3 (the photographing optical axis z1).

The cam-incorporated gear 90 is provided at the front end thereof with a spur gear portion 90a. The cam-incorporated gear 90 is provided immediately behind  
20 the spur gear portion 90a with a first cam surface 90b, and is provided between the first cam surface 90b and the rear end of the cam-incorporated gear 90 with a second cam surface 90c. The cam-incorporated gear 90 is biased  
25 forward by a compression coil spring 90d to remove

backlash. A first follower pin 83a (see Figure 148) projected from the first movable frame 83 is pressed against the first cam surface 90b by the spring force of the first compression coil spring 87, while a second 5 follower pin 84a (see Figures 143, 146 and 148) projected from the second movable frame 84 is pressed against the second cam surface 90c by the spring force of the second compression coil spring 88. A rotation of the cam-incorporated gear 90 causes the first movable frame 83 10 and the second movable frame 84 that respectively hold the first movable power-varying lens 81b and the second movable power-varying lens 81c to move in the optical axis direction in a predetermined moving manner while changing the space therebetween in accordance with the contours 15 of the first cam surface 90b and the second cam surface 90c to vary the focal length of the zoom viewfinder in synchronization with the focal length of the zoom lens 71. Figure 156 is a developed view of an outer peripheral surface of the cam-incorporated gear 90, showing the 20 positional relationship between the first follower pin 83a and the first cam surface 90b and the positional relationship between the second follower pin 84a and the second cam surface 90c in each of three different states, i.e., at the wide-angle extremity, the telephoto 25 extremity and the retracted position of the zoom lens 71.

All the elements of the zoom viewfinder except for the objective window plate 81a and the eyepiece window plate 81h are put together to be prepared as a viewfinder unit (subassembly) 80 as shown in Figure 143. The viewfinder  
5 unit 80 is mounted on top of the stationary barrel 22 via set screws 80a as shown in Figure 5.

The digital camera 70 is provided between the helicoid ring 18 and the cam-incorporated gear 90 with a viewfinder drive gear 30 and a gear train (reduction gear train) 91. The viewfinder drive gear 30 is provided with a spur gear portion 30a which is in mesh with the annular gear 18c of the helicoid ring 18. Rotation of the zoom motor 150 is transferred from the annular gear 18c to the cam-incorporated gear 90 via the viewfinder  
10 drive gear 30 and the gear train 91 (see Figures 146 and 147). The viewfinder drive gear 30 is provided behind the spur gear portion 30a with a semi-cylindrical portion 30b, and is further provided with a front rotational pin 30c and a rear rotational pin 30d which project from the  
15 front end of the spur gear portion 30a and the rear end of the semi-cylindrical portion 30b, respectively so that the front rotational pin 30c and the rear rotational pin 30d are positioned on a common rotational axis of the viewfinder drive gear 30. The front rotational pin 30c  
20 is rotatably fitted into a bearing hole 22p (see Figure  
25

6) formed on the stationary barrel 22 while the rear  
rotational pin 30d is rotatably fitted into a bearing hole  
21g (see Figure 8) formed on the CCD holder 21. Due to  
this structure, the viewfinder drive gear 30 is rotatable  
5 about its rotational axis (the rotational pins 30c and  
30d) extending parallel to the lens barrel axis Z0 (the  
rotational axis of the helicoid ring 18), and is immovable  
in the optical axis direction. The gear train 91 is  
composed of a plurality of gears: a first gear 91a, a  
10 second gear 91b, a third gear 91c and a fourth gear 91d.  
Each of the first through third gears 91a, 91b and 91c  
is a double gear consisting of a large gear and a small  
gear, and the fourth gear 91d is a simple spur gear as  
shown in Figures 5 and 146. The first through fourth  
15 gears 91a, 91b, 91c and 91d are respectively rotatably  
fitted on four rotational pins projecting from the  
stationary barrel 22 in parallel to the photographing  
optical axis Z1. As shown in Figures 5 through 7, a gear  
hold plate 22 is fixed to the stationary barrel 22 by set  
20 screws 92a to be positioned immediately in front of the  
first through fourth gears 91a, 91b, 91c and 91d to prevent  
the first through fourth gears 91a, 91b, 91c and 91d from  
coming off their respective rotational pins. With the  
gear train 91 fixed properly at their respective fixing  
25 positions as shown in Figures 146 through 148, rotation

of the viewfinder drive gear 30 is imparted to the cam-incorporated gear 90 via the gear train 91. Figure 6 through 8 show the zoom lens 71 in a state where the viewfinder drive gear 30, the viewfinder unit 80 and the 5 gear train 91 are all fixed to the stationary barrel 22.

As described above, the helicoid ring 18 continues to be driven to move forward along the lens barrel axis Z0 (the photographing optical axis Z1) while rotating about the lens barrel axis Z0 with respect to the 10 stationary barrel 22 and the first linear guide ring 14 until the zoom lens 71 reaches the wide-angle extremity (zooming range) from the retracted position. Thereafter, the helicoid ring 18 rotates about the lens barrel axis Z0 at a fixed position with respect to the stationary 15 barrel 22 and the first linear guide ring 14, i.e., without moving along the lens barrel axis Z0 (the photographing optical axis Z1). Figures 23 through 25, 144 and 145 show different operational states of the helicoid ring 18. Specifically, Figures 23 and 144 show the helicoid ring 20 18 in the retracted state of the zoom lens 71, Figures 24 and 145 show the helicoid ring 18 at the wide-angle extremity of the zoom lens 71, and Figure 25 shows the telephoto extremity of the zoom lens 71. In Figures 144 and 145, the stationary barrel 22 is not shown for the 25 purpose of making the relationship between the viewfinder

drive gear 30 and the helicoid ring 18 easier to understand.

The viewfinder drive gear 30 does not rotate about the lens barrel axis Z0 during the time the helicoid ring 18 rotates about the lens barrel axis Z0 while moving in the optical axis direction, i.e., during the time the zoom lens 71 is extended forward from the retracted position to a position immediately behind the wide-angle extremity (i.e., immediately behind the zooming range).  
The viewfinder drive gear 30 rotates about the lens barrel axis Z0 at a fixed position only when the zoom lens 71 is in the zoom ranging between the wide-angle extremity and the telephoto extremity. Namely, in the viewfinder drive gear 30, the spur gear portion 30a is formed thereon to occupy only a front small part of the viewfinder drive gear 30, so that the spur gear portion 30a is not in mesh with the annular gear 18c of the helicoid ring 18 in the retracted state of the zoom lens 71 because the annular gear 18c is positioned behind the front rotational pin 30c the retracted state of the zoom lens 71. The annular gear 18c reaches the spur gear portion 30a to mesh therewith immediately before the zoom lens 71 reaches the wide-angle extremity. Thereafter, from the wide-angle extremity to the telephoto extremity, the annular gear 18c remains in mesh with the spur gear portion 30a because

the helicoid ring 18 does not move in the optical axis direction (horizontal direction as viewed in Figures 23 through 25, 144 and 145).

As can be understood from Figures 153 through 155,  
5 the semi-cylindrical portion 30b of the viewfinder drive gear 30 is provided with an incomplete cylindrical portion 30b1 and a flat surface portion 30b2 which is formed as a cut-away portion of the incomplete cylindrical portion 30b1 so that the flat surface portion 30b2 extends along  
10 the rotational axis of the viewfinder drive gear 30. Accordingly, the semi-cylindrical portion 30b has a non-circular cross section, i.e., a substantially D-shaped cross section. As can be seen in Figures 153 through 155, some specific teeth of the spur gear portion  
15 30a adjacent to the flat surface portion 30b2 project radially outwards beyond the position of the flat surface portion 30b2 in a direction of engagement of the some specific teeth of the spur gear portion 30a with the annular gear 18c (i.e., horizontal direction as viewed  
20 in Figure 153). When the zoom lens 71 is in the retracted state, the viewfinder drive gear 30 is in its specific angular position in which the flat surface portion 30b2 faces the annular gear 18c of the helicoid ring 18 as shown  
25 in Figure 153. In this state shown in Figure 153, the viewfinder drive gear 30 cannot rotate even if driven to

rotate because the flat surface portion 30b2 is in close vicinity of the addendum circle of the annular gear 18c. Namely, even if the viewfinder drive gear 30 tries to rotate in the state shown in Figure 153, the flat surface portion 30b2 would hit some teeth of the annular gear 18c, so that the viewfinder drive gear 30 cannot rotate.

If the helicoid ring 18 moves forward until the annular gear 18c of the helicoid ring 18 is properly engaged with the spur gear portion 30a of the viewfinder drive gear 30 as shown in Figure 145, the portion of the helicoid ring 18 which includes the entire part of the annular gear 18c is positioned in front of the semi-cylindrical portion 30b in the optical axis direction. In this state, the viewfinder drive gear 30 rotates by rotation of the helicoid ring 18 since the semi-cylindrical portion 30b does not overlap the annular gear 18c in radial directions of the zoom lens 71.

Although the helicoid ring 18 is provided in front of the annular gear 18c with the set of three rotational sliding projections 18b each having a radial height greater than the radial height (tooth depth) of the annular gear 18c, the set of three rotational sliding projections 18b do not interfere with the viewfinder drive gear 30 during the time the helicoid ring 18 moves between the position thereof at the wide-angle extremity and the

position thereof at the telephoto extremity while rotating about the lens barrel axis Z0 because the rotation of the helicoid ring 18 for driving the zoom lens 71 from the retracted position to the wide-angle extremity 5 is completed while the viewfinder drive gear 30 is positioned in between two of the three rotational sliding projections 18b in a circumferential direction of the helicoid ring 18. Thereafter, the set of three rotational sliding projections 18b and the spur gear portion 10 30a do not interfere with each other since the set of three rotational sliding projections 18b are positioned in front of the spur gear portion 30a in the optical axis direction in a state where the annular gear 18c is engaged with the spur gear portion 30a.

15 In the above illustrated embodiment, with respect to the helicoid ring 18 which rotates about the lens barrel axis Z0 while moving in the optical axis direction in one state and which rotates at a fixed position on the lens barrel axis Z0 in another state, the spur gear portion 20 30a is formed on the specific portion of the viewfinder drive gear 30 which is engageable with the annular gear 18c only when the helicoid ring 18 rotates at its predetermined axial fixed position. Moreover, the semi-cylindrical portion 30b is formed on the viewfinder 25 drive gear 30 behind the spur gear portion 30a thereof,

so that the viewfinder drive gear 30 is prohibited from rotating by interference of the semi-cylindrical portion 30b with the annular gear 18c during the time the helicoid ring 18 rotates about the lens barrel axis Z0 while moving 5 in the optical axis direction. Due to this structure, although the viewfinder drive gear 30 does not rotate while the zoom lens 71 is extended or retracted between the retracted position and a position immediately behind the wide-angle extremity, the viewfinder drive gear 30 10 rotates only when the zoom lens 71 is driven to change its focal length between the wide-angle extremity and the telephoto extremity. In short, the viewfinder drive gear 30 is driven only when the viewfinder drive gear 30 needs to be associated with the photographing optical system 15 of the zoom lens 71.

Assuming the viewfinder drive gear 30 rotates whenever the helicoid ring 18 rotates, a drive transfer system extending from the viewfinder drive gear to a movable lens of the zoom viewfinder has to be provided 20 with an idle running section for disengaging the movable lens from the viewfinder drive gear, because the viewfinder drive gear 30 rotates even when it is not necessary to drive the zoom viewfinder, i.e., when the zoom lens 71 is extended forward to the wide-angle 25 extremity from the retracted state. Figure 157 is a

developed view, similar to that of Figure 156, of an outer peripheral surface of a cam-incorporated gear 90' (which corresponds to the cam-incorporated gear 90 of the zoom lens 71) which is provided with such an idle running section. In each of Figures 156 and 157, the spur gear portion 90a is not shown for clarity.

A first cam surface 90b' of the cam-incorporated gear 90', which correspond to the first cam surface 90b of the cam-incorporated gear 90, is provided with a long linear surface 90b1' for preventing a follower pin 83a' (which corresponds to the follower pin 83a) from moving in an optical axis direction Z3' (which corresponds to the optical axis Z3) even if the cam-incorporated gear 90 rotates. Likewise, a second cam surface 90c' of the cam-incorporated gear 90', which correspond to the second cam surface 90c of the cam-incorporated gear 90, is provided with a long linear surface 90c1' for preventing a follower pin 84a' (which corresponds to the follower pin 84a) from moving in the optical axis direction Z3' even if the cam-incorporated gear 90 rotates. As can be understood by a comparison between Figures 156 and 157, the long linear surface 90b1' consumes a large circumferential range of the first cam surface 90b' to thereby shorten the remaining circumferential range of the first cam surface 90b' which is used as a cam surface

for moving the follower pin 83a' in the optical axis direction; this inevitably increases the degree of inclination of the cam surface. Likewise, the long linear surface 90cl' consumes a large circumferential range of the second cam surface 90c' to thereby shorten the remaining circumferential range of the second cam surface 90c' which is used as a cam surface for moving the follower pin 84a' in the optical axis direction; this inevitably increases the degree of inclination of the cam surface. If the degree of inclination of each of the first cam surface 90b' and the second cam surface 90c' is great, the amount of movement of each follower pin 83' and 84' along the rotational axis of the cam-incorporated gear 90' (i.e., along the optical axis Z3) per unit of rotation of the cam-incorporated gear 90' becomes great, which makes it difficult to move each follower pin 83' and 84' with a high degree of positioning accuracy. If the degree of inclination of each of the first cam surface 90b' and the second cam surface 90c' is reduced to prevent this problem from occurring, the diameter of the cam-incorporated gear 90' has to be increased, which is detrimental to miniaturization of the zoom lens. This problem is also true for the case of adopting a cam plate instead of a cylindrical cam member such as the cam-incorporated gear 90.

In contrast, in the present embodiment of the zoom lens, in which the viewfinder drive gear 30 is not driven when not necessary to rotate, the cam-incorporated gear 90 does not have to be provided on each of the first and 5 second cam surfaces 90b and 90c with an idle running section. Therefore, an effective circumferential range of a cam surface for moving the follower pin 83a or 84a in the optical axis direction can be secured on each of the first and second cam surfaces 90b and 90c without 10 increasing either the degree of inclination of the cam surfaces or the diameter of the cam-incorporated gear 90. In other words, miniaturizing the drive system for the zoom viewfinder and driving the movable lenses of the viewfinder optical system with high accuracy can be both 15 achieved. In the present embodiment of the zoom lens, the first and second cam surfaces 90b and 90c of the cam-incorporated gear 90 are provided with linear surfaces 90b1 and 90c1 which look like the aforementioned linear surfaces 90b1' and 90c1', respectively, due to the 20 fact that the annular gear 18c is brought into engagement with the spur gear portion 30a intentionally at the moment immediately before the zoom lens 71 reaches the zooming range (the wide-angle extremity) when the zoom lens 71 is extended forward from the retracted position in 25 consideration of backlash and play among gears shown in

Figures 146 through 148. Nevertheless, the circumferential lengths of the linear surfaces 90b1 and 90c1 are much smaller than those of the linear surfaces 90b1' and 90c1' of the comparative embodiment.

5 In the present embodiment of the zoom lens, the annular gear 18c is formed so that the spur gear portion 30a of the viewfinder drive gear 30 can smoothly mesh with the annular gear 18c. Specifically, one of a plurality of gear teeth of the annular gear 18c, i.e., a short gear tooth 18c1 is formed to have a shorter tooth depth than those of other normal gear teeth 18b2 of the annular gear 18c.

10 Figures 149 through 152 show the positional relationship between the annular gear 18c of the helicoid ring 18 and the spur gear portion 30a of the viewfinder drive gear 30 in different states in time sequence in the course of variation in state of the zoom lens from the state shown in Figure 144 in which the zoom lens 71 is in the retracted state to the state as shown in Figure 15 145 in which the zoom lens 71 is set at wide-angle extremity. The positional relationship between the annular gear 18c and the spur gear portion 30a is obtained in the middle of rotation of the helicoid ring 18 in a direction from the retracted position to the wide-angle 20 extremity.

Subsequently, the short gear teeth 18c1 approaches the spur gear portion 30a and is positioned in the immediate vicinity of the spur gear portion 30a as shown in Figure 150. Figure 153 shows this state shown in 5 Figure 150, viewed from the front of the viewfinder drive gear 30. It can be seen from Figure 153 that the short gear teeth 18c1 is not yet engaged with the spur gear portion 30a. The normal gear teeth 18c2 are positioned farther from the spur gear portion 30a than the short gear 10 tooth 18c1, and therefore are not yet engaged with the spur gear portion 30a either. No gear teeth serving as gear teeth of the annular gear 18c is formed on a specific portion of the outer peripheral surface of the helicoid ring 18; the specific portion is right next to the short 15 gear tooth 18c1 on one of the opposite sides thereof in the circumferential direction of the helicoid ring 18. Accordingly, at the stage shown in Figures 150 and 153, the annular gear 18c is not yet engaged with the spur gear portion 30a, so that rotation of the helicoid ring 18 is 20 not yet transferred to the viewfinder drive gear 30. In this connection, at the stage shown in Figures 150 and 153, a part of the annular gear 18c still faces the flat surface portion 30b2 to prohibit the viewfinder drive gear 30 from rotating.

25 A further rotation of the helicoid ring 18 in the

lens barrel advancing direction causes to the short gear tooth 18c1 to reach its position shown in Figure 151. At this stage shown in Figure 151, the short gear tooth 18c1 comes into contact with one of the teeth of the spur gear portion 30a and subsequently presses the same in the lens barrel advancing direction (upwards as viewed in Figures 151) to start rotating the viewfinder drive gear 30.

A further rotation of the helicoid ring 18 in the lens barrel advancing direction causes a gear tooth of the normal tooth gear 18c2, which is adjacent to the short gear tooth 18c1 on one of the opposite sides thereof in the circumferential direction of the helicoid ring 18, to press the subsequent gear teeth of the spur gear portion 30a to keep rotating the viewfinder drive gear 30. Thereafter, the annular gear 18c imparts a further rotation of the helicoid ring 18 to the viewfinder drive gear 30 via the engagement of the normal tooth gear 18c2 with the gear teeth of the spur gear portion 30a. At the stage shown in Figure 145 at which the helicoid ring 18 reaches the position thereof at the wide-angle extremity, the short gear teeth 18c1 is not used for the subsequent rotation of the helicoid ring 18 in the zooming range between the wide-angle extremity and the telephoto extremity since the short gear teeth 18c1 has already passed the point of engagement with the spur gear portion

30a.

Accordingly, in the present embodiment of the zoom lens, a portion of the annular gear 18c, which is firstly engaged with the spur gear portion 30a of the viewfinder drive gear 30, is formed as at least one short gear tooth (18c1), the teeth depth of which is smaller than those of the other gear teeth of the annular gear 18c. According to this construction, the annular gear 18c can be reliably and surely engaged with the spur gear portion 30a upon commencement of engagement therewith. Namely, in the case of tall (normal) gear teeth, since the tips of mutually neighboring tall gear teeth having very different relative angles, the engagement thereof is shallow (the initial engagement range is narrow) so that there is a chance of engagement therebetween failing (miss engagement). Whereas, since the short gear teeth 18c1 moves until the relative angle between the short gear teeth 18c1 and the tall gear teeth (the spur gear portion 30a of the viewfinder drive gear 30) becomes substantially the same before engaging, a deeper engagement is achieved (the initial engagement range is wide), so that there is no chance of engagement therebetween failing (missing engagement). Furthermore, this structure reduces the shock at the movement of engagement of the annular gear 18c with the spur gear portion 30a, thus making it possible

to smoothly start operations of the zoom viewfinder drive system including the viewfinder drive gear 30 and to reduce the noise produced by the zoom viewfinder drive system.

5        Although the above descriptions have been directed mainly to the features found in operations of the zoom lens 71 when the zoom lens 71 advances from the retracted position toward the zooming range, similar features can surely be expected in operations of the zoom lens 71 when  
10      the zoom lens 71 retracts to the retracted position.

As can be understood from the foregoing, in the present embodiment of the zoom lens, the second lens group LG2 is retracted to deviate from the photographing optical axis Z1, and at the same time, retracted toward a picture plane to be positioned in the space (off-axis space) radially outside the space (on-axis space) in which the third lens group LG3, the low-pass filter LG4 and the CCD image sensor 60 are positioned. This makes it possible to reduce the length of the zoom lens 71 to a maximum when  
15      the zoom lens 71 is in a fully retracted state; the length becomes considerably smaller than the length of a conventional retractable zoom lens.

In addition, the position of the second lens frame  
6 (i.e., the position of the second lens group LG2) can  
25      be easily adjusted two-dimensionally in directions lying

in a plane orthogonal to the photographing optical axis Z1 with a high degree of precision with a simple structure because the pair of second lens frame support plates 36 and 37 (the front second lens frame support plate 36 and the rear second lens frame support plate 37), which support the pivot shaft 33, can be moved in directions along a plane orthogonal to the photographing optical axis Z1 by rotating the first and second eccentric shafts 34X and 34Y.

10        Additionally, the workability of performing an adjustment of the position of the optical axis of the second lens group LG2 is improved by the aforementioned structure wherein the recess 34X-d, the recess 34Y-d and the cross slot 66b are respectively formed on front ends 15 of the first eccentric shaft 34X, the second eccentric shaft 34Y and the set screw 66 to be accessible from the front of the second lens group moving frame 8, even in a state where the zoom lens 71 is in substantially finished form, i.e., without dismounting fundamental components 20 of the zoom lens 71.

The present invention is not limited solely to the particular embodiment described above. For instance, although the pivot shaft 33 is supported by the two movable support plates (the front second lens frame support plate 25 36 and the rear second lens frame support plate 37) in

the above illustrated embodiment of the zoom lens, in another embodiment shown in Figure 158, only one of the two support plates needs to be movable. Unlike the above illustrated embodiment (of Figure 113), in the embodiment shown Figure 158, a rear protrusion 34X-c' and a rear protrusion 34Y-c' are not eccentric with respect to the adjustment axis PX of a first eccentric shaft 34X' and the adjustment axis PY1 of a second eccentric shaft 34Y', respectively. Furthermore, in a rear second lens frame 10 support plate 37', an engaging hole 37a' which is engaged with a rear protrusion 34X-c' and an engaging hole 37e' which is engaged with a rear protrusion 34Y-c' are not elongated, but rather are formed as circular holes corresponding to the outer diameters of the rear 15 protrusion 34X-c' and the rear protrusion 34Y-c', respectively (i.e., are restricted to move only in a direction perpendicular to the adjustment axes PX and PY1, respectively). Moreover, an engaging hole 37f' is also not elongated, but is formed circular, corresponding to 20 the outer diameter of a rear boss 8k' (i.e., are restricted to move only in a direction perpendicular to the adjustment axes PX and PY1, respectively). The remaining structure is the same as the embodiment shown in Figure 113. According to the construction shown in Figure 158, 25 when the first eccentric shaft 34X' and the second

eccentric shaft 34Y' are each rotated, the rear second lens frame support plate 37' does not move relative to the second lens group moving frame 8, and only the front second lens frame support plate 36 is moved in the X-  
5 direction and the Y-direction. More specifically, when the support plate 36 is moved, the angle of the pivot shaft 33 slightly changes, however, the position of the optical axis of the second lens group LG2 can be adjusted in the same way as the embodiment shown in Figure 113.

10        Although the pivot shaft 33 extends parallel to the photographing optical axis Z1 in the above illustrated embodiment of the zoom lens, the pivot shaft 33, about which an optical element (the second lens group LG2) rotates to the radially retracted position, can be  
15 replaced by a pivot shaft which does not extend parallel the photographing optical axis Z1.

Although the second lens group LG2 serves as a retractable optical element which is to be retracted to the radially retracted position in the above illustrated  
20 embodiment of the zoom lens, the zoom lens 71 can be modified so that any other lens group serves as the retractable optical element or any of the adjustable diaphragm A, the shutter S and the low-pass filter LG4 serves as the retractable optical element.

25        The present invention can be applied not only to a

retractable zoom lens such as the zoom lens 71 as described above, but also to a retractable fixed focal length lens wherein the lens barrel thereof advances from and retracts into a camera body when in use and not in use,  
5 respectively.

The optical element retracting mechanism according to the present invention can be incorporated in not only a digital camera such as the above illustrated digital camera 70, but also in other optical instruments.

10 Although the second lens group LG2 which serves as a retractable optical element is an element the position of which is to be adjustable two-dimensionally in two directions orthogonal to each other in the above illustrated embodiment, such an element can be any  
15 elements other than optical elements. Moreover, each of the above described first and second positioning devices can be provided not only in photographing lenses but also in any other devices.

Obvious changes may be made in the specific  
20 embodiments of the present invention described herein, such modifications being within the spirit and scope of the invention claimed. It is indicated that all matter contained herein is illustrative and does not limit the scope of the present invention.